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SERVO

FOR THE ROBOT EXPERIMENTER

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JUNE 2006

MAGAZINE

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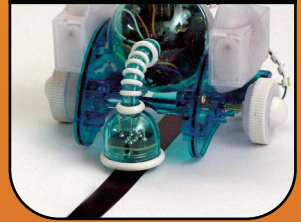
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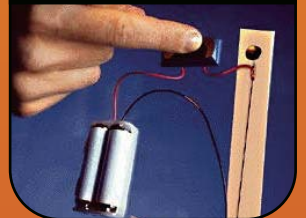
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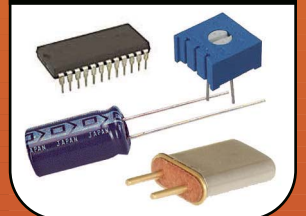
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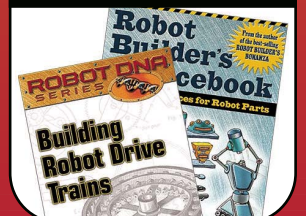
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ROBONOVA-1

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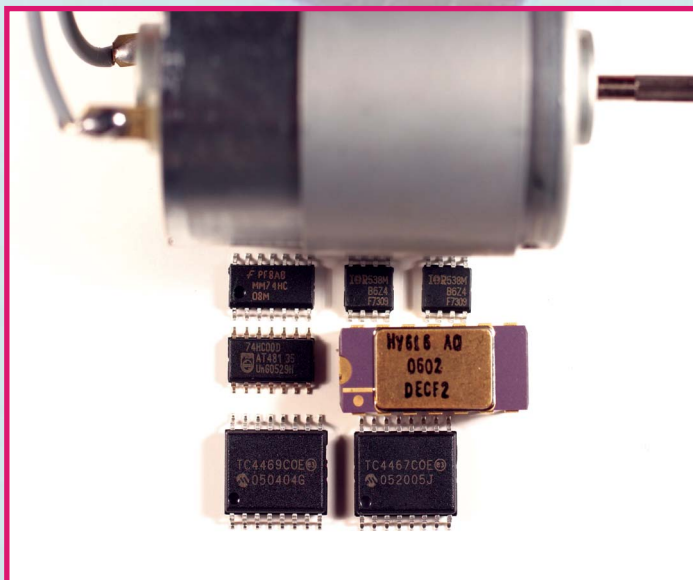
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Walking Robots



Coming 07.2006

Tiny H-Bridge drives stepper and brushed DC motors for bot builds ...

Mind / Iron



by Dave Hryniw, President, Solarbotics Ltd. 

The MAKER Faire — Smallgoods, Revisited

Thirteen years ago, I was a founding member of an informal group of BEAM roboticists self-christened the "Smallgoods," which was named after a favorite Terry Pratchett novel (note the small "g" — we're not that egotistical). We started out as a trio, and soon grew to a collective of 11 members. Every eight to 16 months, one of us would volunteer their house, and we would descend upon it like a plague of locusts from all parts of the world. We traded circuits diagrams and coveted parts, then consumed animal carcasses sacrificed on the barbeque altar to the gods of broken Walkmans and VCRs.

The backgrounds of the Smallgoods were varied, including a robotics scientist, mechanical engineer, prototyping expert, fiber optic specialist, punk rock musician, CAD specialist, school administrator, and security alarm installer. Because of these differences, each of us shared something quite different. We'd leave the event with new insights, and an urge to bring something new back next time.

The halcyon days of Smallgoods passed, as all "Golden Ages" must. I sorely miss them. But the MAKER Faire certainly reminds me of what they were.

As president of Solarbotics Ltd., we were invited to lecture and give workshops at the Faire, and we were very happy to oblige. After fulfilling our daily obligations, we anxiously dove into the pavilions to see what new and cool projects we could devour. It didn't

take long to resurrect the old Smallgoods' habits, and again I was eagerly ignoring my rumbling stomach for the fear of missing something interesting just around the corner.

Although there was a robotics pavilion behind the main stage, not all robot-related projects were hosted here — they were everywhere. Ukrainian Easter-egg decorating machines; autonomous communicating robot blimps; self-drawing etch-a-sketches; interactive self-illuminating dinner tables; silly-string spraying artbots; puzzle-building CNC equipment; homemade Segways and electric unicycles; flap-flying Pterodactyl models; and hand-wired logic-IC-based computers!

Besides the high-tech, there were welding lessons; bicycle-hacking; homemade wind-power generators; massive Lego cranes; medieval armor; fire-breathing vehicles; aerial magic eight-balls; and clothing recycling and redesign! My descriptions do not do the event justice. Seek out some of the many online photo archives — it is worth the effort.

The most spectacular event I saw was held in the back rear corner of the venue — the "Play Day" area hosted by Michael Shiloh. In the purest sense of destructive creativity, the Play Day let anybody tear into a pallet full of dead laptops and technology and turn them into ... well, I saw everything from a trebuchet catapult to a motorized hat! These kids were given permission to destroy a sacred, almost magical device — a laptop — and to explore it completely. Then, they were encouraged to cut it, glue it, tape it, motorize it, and make it something

Mind/Iron Continued 

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BIO-FEEDBACK

Dear *SERVO*:

Glad to see that my manuscript made the April issue. While reading the article, I noticed a problem that crept its way in somehow. The "u" in front of each "F" for each

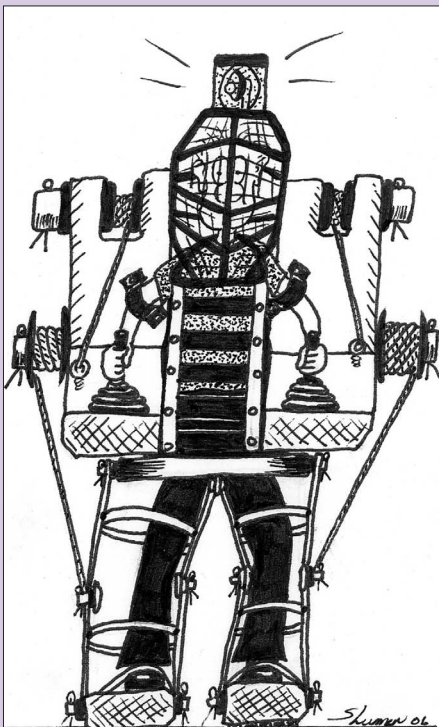
capacitor in the schematics did not make their way from my CAD drawing to the magazine. The ohm symbol didn't make it through either.

The Parts List shows the correct value for all capacitors.

Can you include a note in the next issue of *SERVO* stating that the capacitors in the schematics are actually in μF and not F as shown and that the values in the Parts list are correct?

Rob Caruso

Consider it done ... Ed.



by J. Shuman

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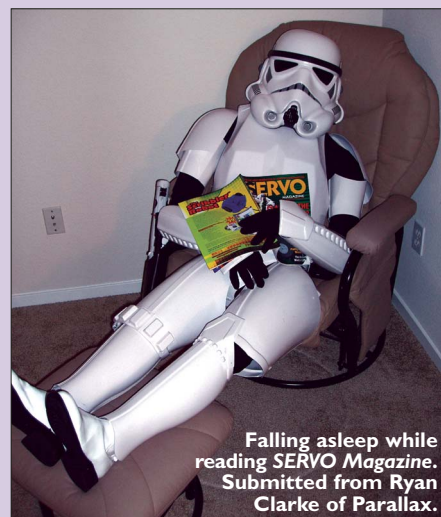
- ☒ BE SURE WARNING LIGHT CAN BE SEEN CLEARLY AND WORKING PROPERLY.

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RULE 45:

- ☐ BE SURE YOU CAN GET OUT OF YOUR TETSUJIN EXO-SUIT.



Falling asleep while reading *SERVO* Magazine. Submitted from Ryan Clarke of Parallax.

purely theirs.

Such rule violations start us engineering-types down the road we travel. The Play-Day workshop was a brilliant introduction to what the theme of the Faire was — to share, to play, and to MAKE.

The MAKER Faire was the opposite to most electronics and robotics trade-fairs I've attended. Very little was labelled "hands-off" to the public. There were no suits, and scant few blatant "for profit" commercial booths. The worst were the food vendors selling \$2.50 bottled water and \$7 roast-beef sandwiches.

Many workshops were designed to give explicit "how-to" instructions, with no secrets held back. Fuelled by enthusiasm and pride, exhibitors ran their demos to exhaustion or destruction. The commercial sponsors

pretty much all seemed to "get it" — this wasn't a time to show off, but just ... to show.

In this age of corporate secrets and patent lawyers, it was nice to be surrounded by the spirit of pure communal creativity. Where I was reliving my days as a "Smallgod," I'm sure others were nostalgic for the "The Homebrew Computer Club" that fostered the high-tech boom in Silicon Valley.

As a roboticist, I felt right at home in the MAKER lounge listening to homemade techno music composed from 10 wired thimbles on the hands of the DJ. I felt welcome inspecting cardboard StarWars "Star Destroyer" hats. I felt I was in familiar company with the GRL crews who were turning a bus into electronic graffiti art.

I wasn't sure what to expect in San

Mateo, CA, but I am glad we contributed. A long time has passed since Smallgods, and I now realize those special events like it no longer have to be just a memory. My sincere congratulations to Mr. Dale Dougherty and his fine crew at MAKE. My sincere thanks to the participants who shared their creations with me. I know our little lectures and workshops found an appreciative audience — thank you for taking time away from the rest of the Faire to learn about BEAM robots!

If you are given the opportunity, participate. Share. Show. Don't wait for a Faire or exhibition. Get to updating your website or blog. Write that article for *SERVO*. Want some fun? Show your robots to a local elementary school.

You will find that when you participate, you will discover fellow Smallgods. **SV**



by Jeff Eckert

Are you an avid Internet surfer who came across something cool that we all need to see? Are you on an interesting R&D group and want to share what you're developing? Then send me an email! To submit related press releases and news items, please visit www.jkeckert.com

— Jeff Eckert

Stealth UUV Launched



The Talisman AUV from BAE Systems is powered by thrusters supplied by Seaeeye Marine. Photo courtesy of Seaeeye.

Adding to the plethora of strange things that are lurking in the undersea environment is BAE Systems' (www.baesystems.com) new autonomous unmanned underwater vehicle (UUV), the Talisman. The vehicle is based on an innovatively-shaped carbon fiber composite hull, equipped with internal carbon fiber composite pressure vessels containing the electronics systems and payload. The hull is fitted with commercial off-the-shelf vectorable thruster pods provided by Seaeeye Marine (www.seaeeye.com), which allow it to maneuver very accurately, hover, and turn 360 degrees within its own length. The hull was designed and manufactured by stealth aircraft technology experts at the BAE Systems military aircraft sites in the U.K. According to the company, Talisman is "capable of a wide range of maritime littoral operations," which is a

bit vague, but we can presume that the stealth design makes it highly suitable for military operations. All mission parameters are pre-settable before launch, allowing fully autonomous operation, but operator intervention is possible during a mission. Communications to and from the vehicle are via RF or Iridium SatCom (while the vehicle is surfaced) and via acoustic communications systems (when the vehicle is underwater). The standard model comes equipped with a suite of environmental sensors, but it can be adapted to mission-specific payloads.

Benchtop Bot for Lab Applications

Protecdyne Corporation specializes in robotics for academic, drug discovery, and commercial reference laboratories. The company recently unveiled the Radius robotic system, which is designed with a radial arm to provide flexibility for applications in diagnostic testing, as well as biotech and pharmaceutical research. Radius is driven by an inverted selective compliance assembly (SCARA) robot to allow for the most usable work space on deck. This robot can also reach outside its frame, offering greater device integration options. While reduced in size, Radius retains the essential components of robust industrial automation



Protecdyne's new Radius system is a more compact version of the BioCube system shown here. Photo courtesy of Protecdyne.

and utilizes the company's exclusive interchangeable SmartTools™. The robot can automatically pick up the correct tool on the fly, without user intervention. Details are available at www.protecdyne.com

Roboraptor Upgrade



WowWee's Roboraptor will soon include vision and navigation systems. Photo courtesy of WowWee Robotics.

On a more entertaining level, Evolution Robotics (www.evolution.com) recently announced that it is teaming up with WowWee Ltd. (www.wowwee.com) to produce what it is billing as the first mass-market robots to be truly intelligent and autonomous. WowWee — which is known for its Roboraptor™ and Robosapien products — will incorporate two of Evolution's technologies in their line of products: ViPR™ and Northstar™. ViPR (for visual pattern recognition) provides reliable and fast recognition of patterns, objects, and locations in realistic environments. Northstar, referred to as "indoor GPS," is said to be the world's lowest-cost solution for position-awareness for consumer robots, enabling them to navigate autonomously and intelligently. Both of these technologies will be used by WowWee as they continue to create new robotic companions and entertainment

products. WowWee president Richard Yanofsky observed, "Consumers want intelligent robots that can function autonomously, whether for pure entertainment purposes or to perform useful tasks such as fetching a beer or even helping to carry the groceries. Working closely with Evolution Robotics, we will be able to deliver these capabilities in our next generation of products."

Danger, Will Robinson

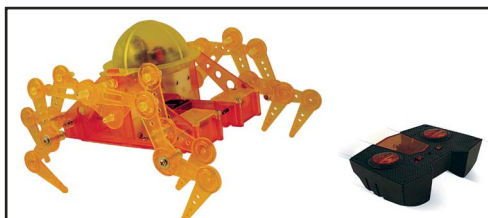


"Lost in Space" bots are now available. Photo courtesy of B9Creations.

More than 40 years after the classic television show, "Lost in Space," debuted, you can finally get a full-size, limited edition, licensed replica of the show's B9 robot. B9Creations, LLC (www.b9creations.com) recently announced completion of the first 10 of them and plans to produce 30 to 50 of them per year. While it appears to be limited in terms of actual robotic functions, the torso is motorized and can be made to rotate via a remote control, the head rotates, the arms retract and extend, and the claws rotate, open, and close. It includes an 240 W internal stereo sound system and the ability to play more than 500 voice tracks by Richard Tufeld, who provided the voice of the original robot. These are stored in Flash memory and can be updated and customized. It also features an external

input jack so you can use it as a normal stereo. The official price is a hefty \$24,500, but the company claims that there is a waiting list of purchasers.

Low-Priced Spider Bot



The Space Nine robot from Carl's Electronics. Photo courtesy of Carl's.

If you're looking for a simple (for ages 10 and up) and reasonably priced robot kit, you might check out the new Space Nine robot kit from Carl's Electronics (www.electronickits.com). The eight-legged "star explorer" is operated via an infrared remote control, and it can walk on rough surfaces, turn right or left, and walk across rocks. It comes in solder and non-solder versions and will run you only \$34.95.

Robot Exposition Keynote Speaker Announced

It was recently announced that Major General Charles Cartwright, Future Combat Systems (FCS) Army Program Manager, will deliver a keynote presentation at the RoboBusiness Conference and Exposition, which is said to be the only industry event dedicated to the growth and development of the mobile robotics and intelligent systems industry. General Cartwright's keynote address is aimed at providing members of the robotics and business communities with an opportunity to learn about the Future Combat Systems program in general, and specifically the many business and partnership opportunities available throughout the design, development, and production phases of the FCS program. The conference and expo will be held at the Sheraton Station Square in Pittsburgh, PA, on June 20 and 21. Information for attendees is available at www.robobusiness2006.com **SV**

every once in a while
something comes along
and revolutionizes the industry

this isn't it,
but it's still freakin' cool.



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The new GM11a, 12a, 13a, 14a & 18 from



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GEER HEAD

by David Geer

Contact the author at geercom@alltel.net

ROBOTS Down on the Farm!

A university and a small farm equipment company and its academic and corporate stakeholders are helping to bring farming into the 21st century, robotically.

The University of Warwick's manufacturing and horticultural groups are collaborating on two farm labor robots in order to lead a farm-based robotic revolution over the next 10 years.

Research students Jim Rowley and John Oliver of the University of Warwick (UK) have developed robots that will soon be working "down on the farm." Jim is responsible for the creation of a robot mushroom-picker, which is getting close to being ready

for production. John is the creator of an autonomous system for controlling existing robotic mowers as they work autonomously in tandem.

Tony Botsman — CEO of Aeropick and inventor — is responsible for bringing farmers a mobile, inflatable, multi-tasking conveyor belt system. Botsman's Aeropick was aided by the UK's Plastics West Midlands and Warwick Ventures companies, which offer resources to help companies like Aeropick with product design and development, and several other partners.

Of the three projects, the mushroom-picker is the most robot-like in appearance.

See and Size, Suck and Pluck

In the UK, mushroom farmers have been hit hard by the import of cheaper mushrooms from Eastern Europe. In fact, about half of the mushroom farmers have had to shut down operations over the past 10 years.

In response, the robot mushroom picker is being developed to make UK mushroom farming cheaper. The many goals for the picker are: pick many more mushrooms, much faster than a human laborer, at the perfect picking size per customer specs, without damaging the mushrooms in the slightest.

The picker consists of a robot arm and suction cup for picking, a CCD (charge coupled device) camera for eyeballing mushrooms that need to be plucked, and a computer and program that feed X, Y mushroom location data to the arm. The robot's controller uses a programming language called VAL+, which is a standard controller programming language.

The robot arm has six joints for six degrees of freedom of motion. In operation, it reaches

The robot mushroom-picker after twisting off another mushroom and stem using its suction cup and vacuum.



View of the complete mushroom-picking robot arm and growing tray. By speeding up the picking process through various modifications, using several arms and trays and operating 24 hours a day, this robot will pick more and better quality mushrooms faster than a human laborer.



out from its base to place its suction cup atop the selected mushroom. Once the vacuum is turned on and the mushroom's head is secured, the robot both moves side to side and twists the mushroom to break it off from its stem.

The vacuum is applied through a small blue hose, which can be seen in the mushroom-picking robot images. The degree of suction must be just right so as not to damage the edible fungi. The suction cup itself has a very soft padded surface, which is also intended to keep the mushrooms intact while they are being harvested.

The next version will have four suction cups (instead of one) that can rotate so that the robot can pick four mushrooms very quickly. Each suction cup will rotate, plucking one mushroom and moving it out of the way. Then, the next suction cup can pick the next mushroom and so on. It will be the equivalent of a human picker picking four mushrooms with a single hand, if a human being could do so.

The mushrooms need to be just the right size for picking, dependent on mushroom type and the requirements of the purchaser. The camera and computer program determine the size by the number of pixels in the mushroom's image. A scaling factor is used to precisely determine size from the pixel information.

The mushrooms are imaged as bitmaps so that each mushroom is recorded as a certain number of pixels. By knowing how many pixels the mushroom is and the distance it is from the camera, researchers can work out the true size of the mushroom. This method of measuring size for picking is more accurate than the human eye.

The digital camera maps the location of each mushroom by using colored pixels. The mushrooms are easily detected as white objects set against the black compost in which they are nursed. The camera currently determines the X, Y coordinates of three mushrooms at a time that are ready to be picked. It sends the X, Y coordinates to the robot.

Researchers are adding a Y axis to determine the exact height of the

mushroom so that the robot can secure the mushroom more quickly without pushing it down, again, so as to avoid damaging it.

Communications from the camera to the arm come over Ethernet. "We are putting in a laser sensor that will give precise Z coordinates to speed things up [to increase accuracy and there by the number of mushrooms that can be picked per minute]," says Dr. Ken Young of the Warwick Manufacturing Group at the University of Warwick.

The picking speed is currently about three mushrooms in 20 seconds, which is about half the speed of a human being. The goal is to achieve a speed of one mushroom every two seconds; this should be achieved once the laser and several other modifications are successful.

The ultimate design for this research is a large mushroom farm using multiple robot pickers and mushroom trays. A cost breakdown has been done on installing all the hardware. The savings are in terms of what is no longer required for the harvesting.

The technology is currently expected to pay for itself in about four years from time of implementation based on these costs and the savings. This is important because local (UK) farmers need to see a savings quickly before they are put out of business by cheaper imports. Researchers are working to reduce the amount of time it will take for the hardware to pay for itself.

Robots can pick continually — 24/7 — without need for rest or remuneration, which is hoped to help produce the needed savings.

Better Than a Field Full of Hungry Goats!

Or, a handful of farm hands riding trac-

tors with lawn mower attachments. Warwick researchers are working on a means to manipulate multiple, robotic lawn mowers to mow large fields in tandem autonomously.

The project, in its early stages, has taken an existing robotic radio controlled grass cutter and pulled the controller off of the mower, replacing it with a PC. The PC is connected to two radar sensors for 360-degree sensing coverage. It also uses two GPS systems: one expensive and elaborate, and one quite cheap.

The mowers will be equipped with radios to broadcast their locations to each other. The two radar sensors will be used to detect each other and to determine their own relative location when the GPS systems are ineffective (more on this later). The two GPS systems are also used to determine their location and to avoid each other.

The actual technology is built around an existing mower model called the Ransomes Spider, made by a Czechoslovakian company called Dvorak Slope Mowers. The mower is designed to mow banks efficiently, with up to 40-degree slopes.

At this point, researchers have replaced the human-operated remote control on a single mower with the PC setup and added the sensors. Eventually, one farm employee will be able to task multiple mowers

Robot grass cutter for cutting banks (and everything else).





Towed apparatus that uncoils and deploys the inflatable conveyor belt.



The conveyor belt is being stretched across its rollers before inflation.



The conveyor belt is separated by dividers to keep the pickings in place and from bouncing around too much.

through a single PC.

Once the mowers have been fueled, the farm hand can punch in programmed tasks (areas to mow) and leave the mowers and system to their work. The robots will mow away autonomously without bumping into each other and still cover all the area that needs trimming.

Hurdles remain that must be overcome to create a fleet of autonomous mowers that mow large areas in tandem. A primary hurdle is that trees degrade the GPS signal. So, via GPS alone, you can't know exactly where the robot is if the trees are in the way.

DARPA GRAND CHALLENGE COMPETITORS HAVE IT EASY?

The DARPA Grand Challenge competitors have an easier time navigating the desert than the robot grass cutters will have autonomously cutting grass, according to Dr. Ken Young of the Warwick Manufacturing Group, University of Warwick.

While the Grand Challenge is held in the desert with no trees and generally a good view of the sky with access to numerous satellites, the grass cutters have to deal with tree obstacles that confuse GPS and the availability of only one GPS satellite, which hovers low to the horizon, says Young.

Young's group has to add more and more sensors to the grass cutters to deal with these hurdles. In the process, they are determining which sensors are most accurate under which conditions.

All sensors work well under optimal circumstances, but a sensor must be available that works well in situations where none of the others will.

The radar sensors were added to take up the slack for the GPS, but there are still cases where neither technology is able to provide the mower's exact location.

While the particular mowers used in research are a good existing platform for experimentation, other types of mowers may be selected as most optimal when the technology is ready for production, based in part on the needs of the farmer.

"Conveying" the Message About Faster Produce Processing

Aeropick markets portable, inflatable, remote-controlled conveyor belt systems for harvesting. The system was developed by Tony Botsman, Aeropick, and its suppliers and stakeholders including the Universities of Warwick, Coventry and Birmingham, Honda Europe, The BHW Group (makers of

winches), and Soga/Sincro (Italy, makers of electric motors).

The inflatable conveyor belt is cushioned so that fruit and vegetables can be quickly picked and dropped on the conveyor system without risk of bruising the harvest. This makes for a speedy harvest, saves steps as pickers don't have to pick the harvest off the ground after separating it from the trees or bushes (in the case of high-growing edibles), and in the same stroke saves the laborer from back pain.

Crops can be picked, processed, washed, and passed on to cool storage on the belt system right out in the field assuming, of course, that the farmer has portable cool storage, such as a refrigerated truck.

Each system is "self-contained" with electric drives controlled by an inverter. A radio band that enables the individual operation of each drive controls the inverter. The technology itself can be operated by a

The Aeropick inflatable conveyor belt has varying widths, in this case perfectly fitting standardized trays of these vegetables.



Laborers only need to carry trays of vegetables as far as the conveyor, saving farm hand person hours.



single farm hand while others do the picking.

The system (protected by global PCT patents) is available with one of three deployment technologies. The system comes with either its own "truck" – the VariTrak Brumby – which is a self-propelled vehicle, a trailer mount that can be towed, or a three-part linkage with a diesel-generated set of 10 KVA or one 20 KVA PTO drive(s).

The system provides its own power, including a surplus 10 KVA to power the processing, cooling, washing, and sorting in the field. The system uses a hydraulic differential lock braking system to maintain footing on difficult terrains.

Aeropick system conveyor belts now stretch up to 150 meters.

Conveyor speed is variable and remote controlled at between 10 to 30 meters a minute. At that speed, according to Botsman, a farmer can move up to 20 tons of produce an hour. The belt has a variable width of from 1 to 1.5 meters, which is suitable for a variety of standard crop tray spacings. The belt can be inflated in just a few minutes.

The Aeropick will pay for itself in one planting and harvesting season of use. This results from savings on labor costs where a workforce of only 30 farm hands paid an equivalent of \$8.00 US per hour of work for one season using the Aeropick.

Botsman and company are currently looking for franchisees in the US and the Americas. **SV**

RESOURCES

Film of mushroom-picking robot
www.research-tv.com/stories/technology/mushroom/bb/

University of Warwick
www2.warwick.ac.uk

Some farm robot news can be found here, but you'll have to do some digging
www.agriseek.com/?AUT=ed85ba94afdc00780503b9cc5c3ab1b4d546d4164&FF_UMX=Y

Aeropick – Makers of the inflatable conveyor belts
www.aeropick.com

Dvorak Slope Mowers
www.spider-cz.com

Coventry University
www.coventry.ac.uk

University of Birmingham
www.bham.ac.uk/default.asp

Honda Europe
www.honda-eu.com

BHW Group
www.bhwgroup.com/

The Soga Group
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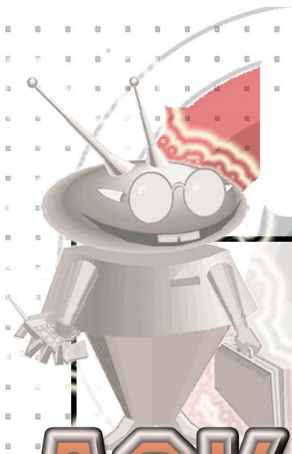
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10

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ASK MR. ROBOTO

by
Pete Miles

Q. I have a mini sumo that uses three of the long range Sharp GP2Y0D02YK. I have the sensors mounted to the sides of my robot and one at the front. Basically, my robot will attack anything the front sensor sees, and when the side sensors see a robot, it will spin around until the front sensor sees the other robot. Then it will attack that robot. The problem I am having is that when I am at home, the robot sees my hand with no problem and will always go after it. But when I go to tournaments, most of the time my robot doesn't see the other robot, and ends up spinning in a circle looking for the other robot. Do you have any suggestions that could help me?

— **Steve Nations**

A. The Sharp GP2Y0D02YK Long Distance Measuring Sensors are one of my favorite sensors to use in any robot. They are quite reliable and not very prone to surrounding light interference. I have had these sensors detect as small as a 0.020 inch diameter wire, two feet away from the sensor. But there are a couple things that you need to keep in mind when using these sensors to field them effectively.

First off, these sensors are reflective sensors, and they require a portion of the original narrow beam of infrared light to be reflected right back at the sensor, or it doesn't "see" or sense any-

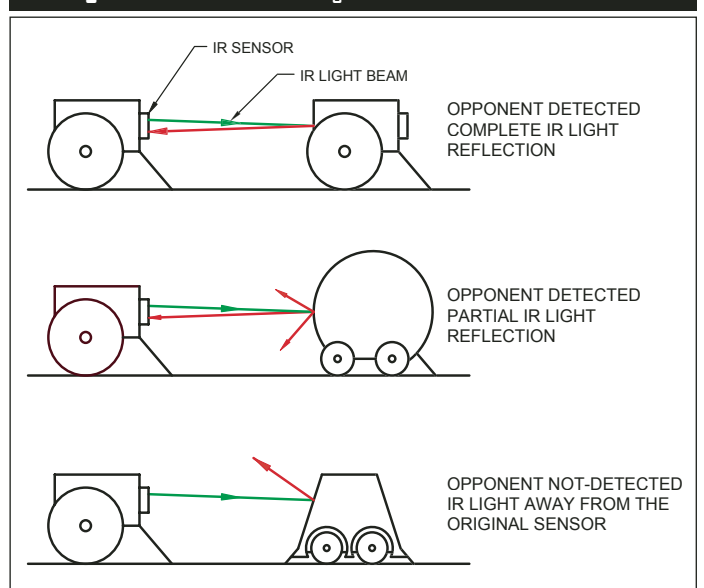
thing. Your hand is one of the better surfaces for reflecting light back to the sensor. It has many irregular surface, wrinkles, creases, and folds that almost ensures that you will be reflecting some portion of the IR light back at the sensor. But a robot has a lot of flat surfaces that tend to reflect the light away from the sensor, not back to the sensor.

To illustrate this, place a clean mirror in front of the sensor. If the orientation of the mirror is such that all of the IR light is reflected back to the sensor, then the sensor will always detect the mirror. But if you start angling the mirror upwards, or to the sides, the sensor will stop "seeing" the mirror that is right in front of it. The closer the mirror is to the sensor, the greater the angle (which is only a few degrees) that the mirror needs to be misaligned for the sensor to stop seeing the mirror. What gets worse is that as the distance between the mirror and the sensor increases, the more precise the angular orientation must be in order for the

sensor to detect the mirror. Past two feet, the mirror has to be almost perfectly aligned in order for the sensor to see the mirror. Figure 1 shows a simple illustration of this.

Fortunately, these sensors are very sensitive, so that any imperfection on the surface of the target is more likely to cause light to be reflected back to the sensor. An easy way to observe this is to conduct the same tests with a piece of flat metal or plastic. You will find that you can have greater angles on the target surface for the sensor to see it. The rougher the surface, the greater the angular misalignment can be for detecting the target.

Figure 1. Illustration of angular refraction for IR sensors.



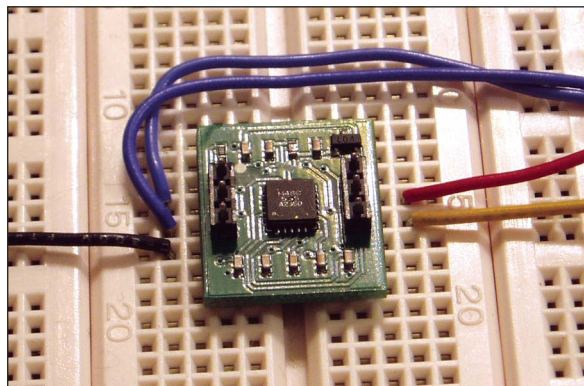


Figure 2. Hitachi H48C three-axis acceleration module from Parallax, Inc., mounted on a breadboard.

Now how does this relate to a mini sumo? Well, they have lots of little parts and edges that do a good job at reflecting IR light back to the sensor. But the angles of the surfaces on all these little parts — with respect to your robot — is constantly changing. So there will be times that your sensors will get a good strong return signal, and there will be other times when the other robot is right in front of yours, and the sensors don't see it at all.

So it is always better to test your robot tracking sensors against other robots to see how well they work. This often overlooked flaw in using reflective sensors can also be used to your advantage. If you place angled plates on the sides of your robot, you can force your opponent's IR sensors to reflect up in the air. This will, in effect, make your robot invisible to the other robots.

The second problem with these sensors is the ~50 ms time delay between each measurement. These sensors work by sampling a certain number of return signals to determine if the input is real before outputting the result. This sampling period takes about 40 ms, and there is about a 10 ms delay before an output occurs. This means that the other robot must be in the sensor's field-of-view for about 40 ms and returning a lot of reflected IR light back to the sensor, or it won't detect the robot.

If the robots are moving slowly, then this usually isn't a real problem. But in the case of the spinning

robot/sensor, then the amount of time the sensor's IR light is on the opponent will be much less than if the robot is driving past your robot on its own. The faster your robot is spinning, the less likely the sensors will see the robot. Not only is there less time for the sensor's IR light to be on the other robot, but the angular reflections will be worse because the IR light beam is traveling in an arc.

The approach that you are using in your robot to spin around and stop when the forward sensors see its opponent is a good one, and I have used it myself. What you need to do is slow down the spin rate, and add a spin time delay that will stop the robot from spinning if it doesn't detect an opponent. For example, you could set the time delay to limit the robot to spinning only 90 degrees, or one complete revolution before continuing to move forward.

With all this being said, you should be able to improve your mini sumo robot's performance with a little bit of software adjustments by limiting how much the robot spins in a circle, and reducing the speed in which the robot spins. Hopefully this helps you.

Q . Do you know of any good sensors that can determine if your robot is upside down or on its sides so that it can automatically flip itself back upright?

— Lee Banks

A . Parallax, Inc. (www.parallax.com), has a new three-axis accelerometer module that should work well for your application. This module uses a single Hitachi (www.hitachi.com) H48C three-Axis accelerometer that is capable of measuring ±3gs of acceleration on each axis (an example code is available on the *SERVO* website at www.servo-magazine.com). The module includes a built-in 3.3 voltage regulator so that the module can be used with standard

five-volt circuits, and it uses the Microchip (www.microchip.com) MCP3204 four-channel 12-bit analog-to-digital (ADC) converter with SPI serial interface. The MCP3204 ADC uses the SPI serial interface protocol that is compatible with the SHIFTIN and SHIFTOUT commands on a BASIC Stamp.

The module is relatively small, only 0.7 inches by 0.8 inches in size, and its six I/O pins can be mounted on any standard breadboard. Figure 2 shows a photograph of the module. When the sensor is not moving, it can measure the gravitational pull of the Earth, and the values read on the x, y, and z axis of the sensor will tell you the orientation of the accelerometer with respect to the Earth. By knowing the orientation of the accelerometer on the robot, you can determine the orientation of the robot with respect to the ground.

What makes this sensor attractive is that it can measure all three axis at the same time. Most other low-cost accelerometers only measure two axis, and a robot would require a pair of these sensors to obtain 3D information. In addition, the circuit board for the other accelerometers must have a vertical extension for mounting the second accelerometer, and making sure that the two accelerometers are at 90 degrees with respect to one another is difficult.

The following formula is used to determine the acceleration on each of axis of the accelerometer, where G_{axis} is the acceleration in gs on a particular axis, $Axis$, and V_{ref} is a self calibration reference voltage.

$$G_{axis} = \frac{Axis - V_{ref}}{366.3 \text{ mV/g}}$$

Since the MCP3204 converts the analog voltage from the H48C into a 12 bit binary number, the microcontroller must convert this back into a number that is easily understood. The following formula shows how the 12 bit counts for $Axis$ and V_{ref} are converted into a numerical number. The 4095 is the maximum number of counts for a 12 bit number,

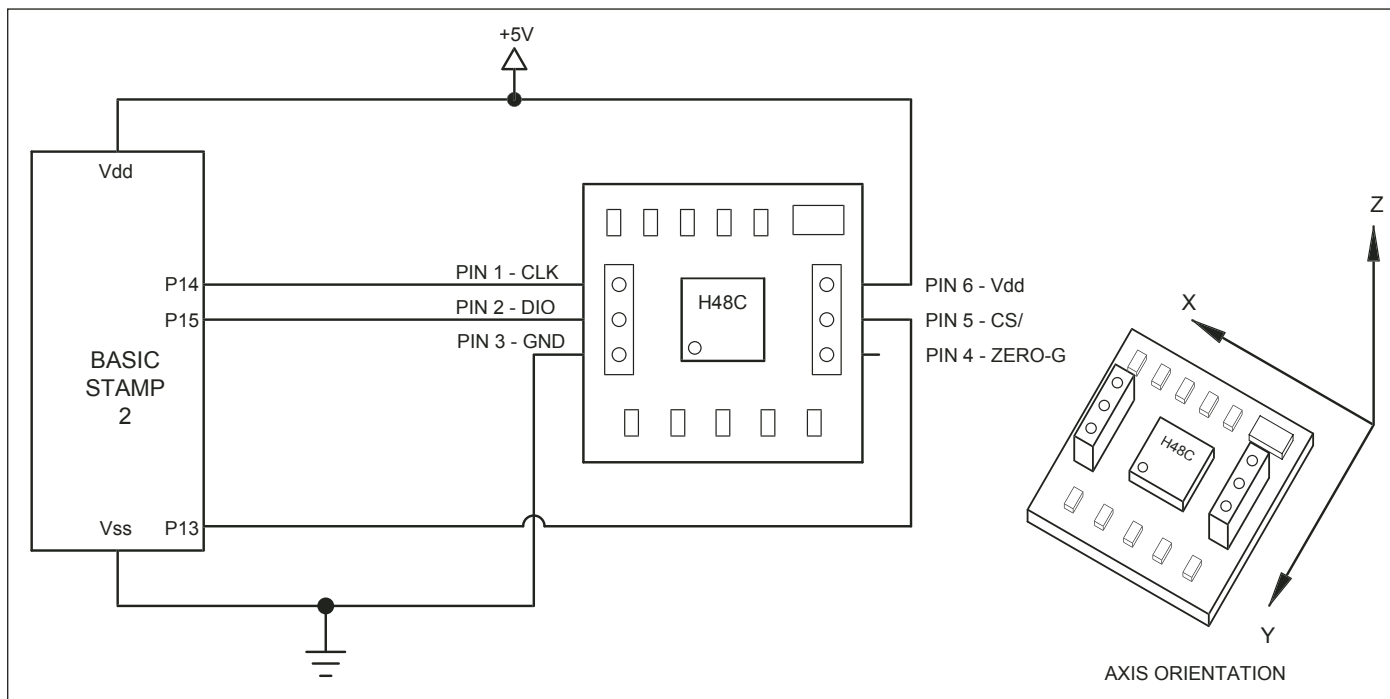


Figure 3. Wiring the Hitachi H48C acceleration module to a BASIC Stamp.

and 3.3 V represents the maximum voltage span.

$$G_{axis} = \frac{Axis - V_{ref}}{366.3 \text{ mV/g}} * \left(\frac{3.3V}{4095} \right)$$

Figure 3 shows a simple schematic for hooking up this sensor to a BASIC Stamp, and the example programs shown here illustrate how to read the acceleration values. Once the acceleration values have been read in

for all three axes, the Orientation subroutine is called in this example program. Here this routine assumes that the Z-axis of the sensor is pointing up towards the sky when the robot is on flat level ground, and the Y-axis is pointing towards the front of the robot.

Figure 3 also shows the orientation of the three axes on the accelerometer module. Right now, this routine will tell you if the robot is vertical or inverted

(i.e., upside down) and whether the robot is leaning forward and/or to the sides. In your application, you would want to add some threshold values to tell the robot to execute corrective actions if the threshold values are exceeded. For example, if the robot is leaning to the side by more than 45 degrees, chances are that is about to fall over, thus it should start turning towards that side to prevent rolling over. **SV**

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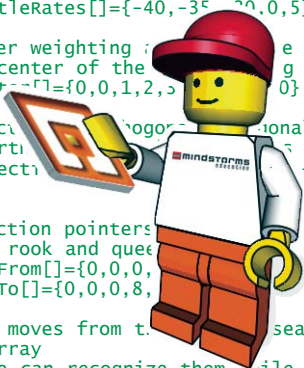

```
// castling bonuses
B8 castleRates[]={-40,-35,20,0,5};

//center weighting
//the center of the board is preferred
B8 centerWeights[]={0,0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15};

//direction pointers
//the center of the board is preferred
B8 directionWeights[]={0,0,1,2,3,4,5,6,7,8,9,11,9,10,-10,1,-11};

//direction pointers
//the center of the board is preferred
B8 dirFrom[]={0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0};
B8 dirTo[]={0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0};

//Good moves from the search are stored in this array
//so we can recognize them while searching and make sure they are tested first
```



LESSONS FROM THE LABORATORY

A bi-monthly column just for kids!

A Sneak Peak at the NXT Software

by James Isom



This month, we take a quick look at the soon to be released software for the LEGO Mindstorms NXT. Specifically, we will be looking at the educational version of the software. It has a few features that the retail toy set doesn't, but functionally they

should both be about the same.

Let's fire it up and have a look.

The opening screen (see Figure 1) is broken into two parts. On the left are the quick start guides – two brief tutorials to get you up and running in a minimum amount of time. On the right

is the Robot Educator, home to 40 lessons that introduce you to the core concepts of building and programming with Mindstorms NXT.

Each lesson consists of a Challenge Brief, Building Guide, and Programming Guide. Lessons use extensive rendered video or slide show

FIGURE 1. The Startup Screen.

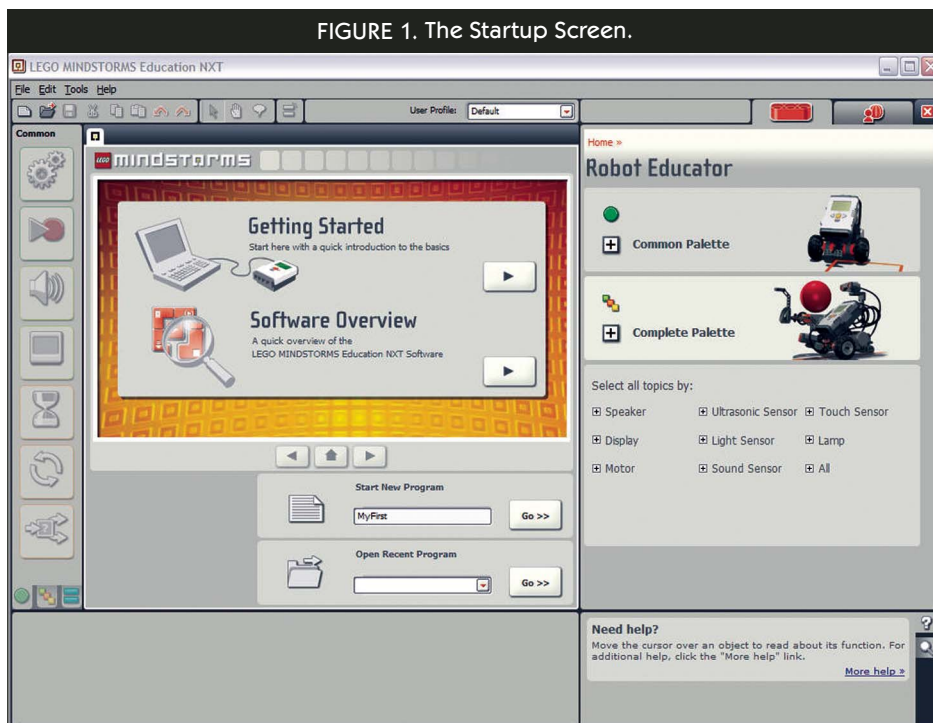
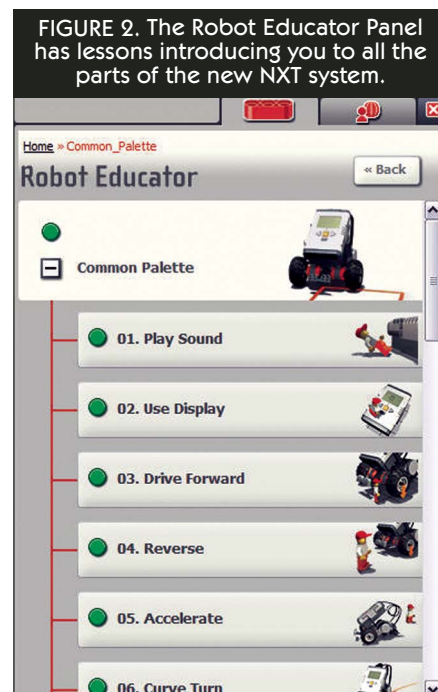


FIGURE 2. The Robot Educator Panel has lessons introducing you to all the parts of the new NXT system.



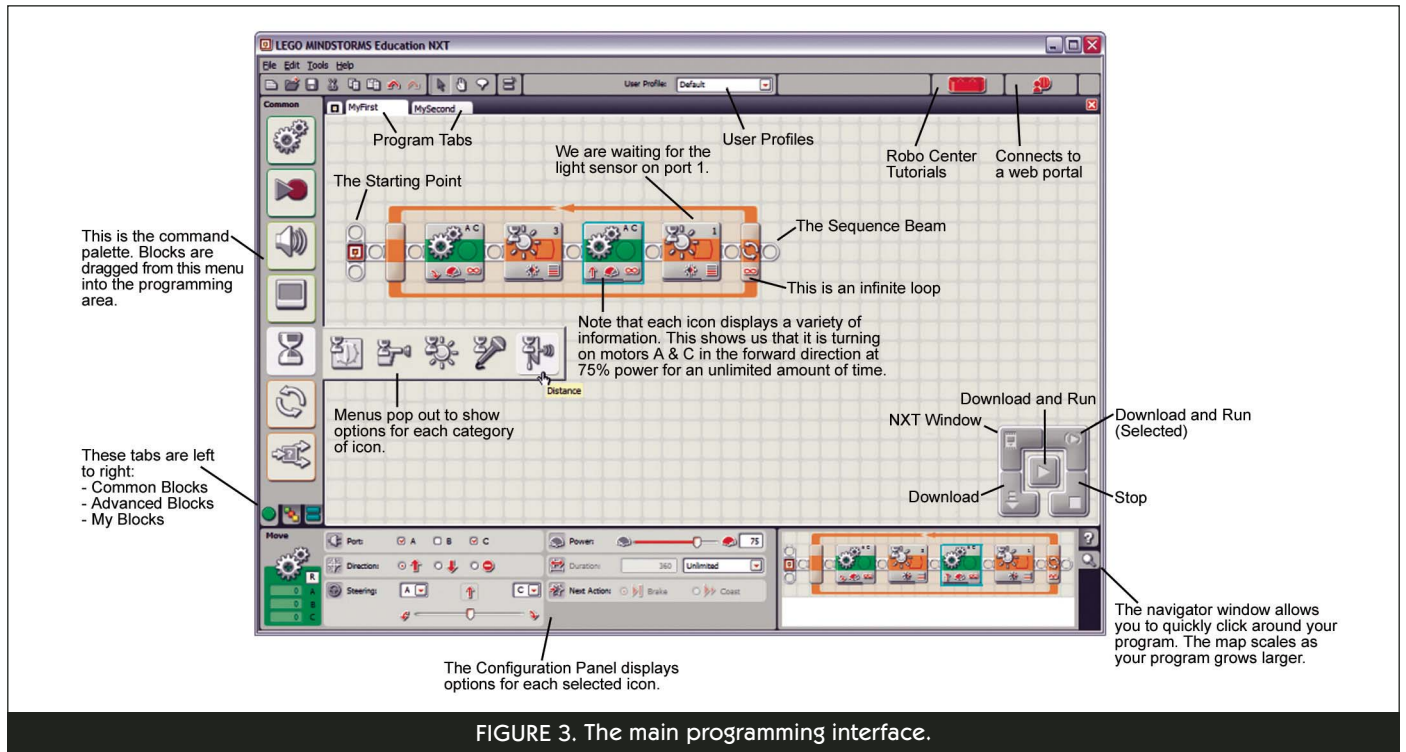


FIGURE 3. The main programming interface.

presentations to deliver the concepts quickly and clearly. The build instructions are similar to those found in a typical LEGO constructopedia and can be blown up to fill the whole screen or viewed from within the Robot Educator sidebar (see Figure 2).

All the lessons are organized by palette and by topic, making it easy to find just what you're looking for. If you need a more in-depth explanation, the browser-based help files can be launched via a link found in the lower right hand corner of the screen. After plowing through the lessons and the help system, it becomes clear that the NXT has a lot to offer both the new and experienced user.

Building a Program

Starting a new program is as simple as typing in a name and hitting the "go" button. This brings you to the main programming interface, which is shown in Figure 3.

At first glance, it seems the NXT

software has borrowed a bit from its icon-based predecessors – the Robotics Invention System (RIS) and Robolab.

It has an RIS type docked palette of programming blocks and a left-to-right wired programming style familiar to Robolab users. Let's start by looking at each section of the programming interface.

The Common Palette

In order to help users find what they are looking for, the programming blocks have been organized into a couple of palettes. The first of these is the Common Palette. It holds the following icons, loosely broken up into two groups identified by their color borders: green action blocks and orange structure blocks.



Move: Controls all three output ports. With this one icon, you can control the motors of all three ports, including the direction, steering, power level, and duration of

the movement. You also have the option to set whether the motors brake or coast into the next action.



Record and Play: For those of you who remember the LEGO Inventor Record & Play set released in 2003, the functionality of this block will be familiar to you. It allows you to record a motor action and play it back.



Sound: Plays a digitized sound file or a generated tone. The NXT software comes with over 100 sound files for you to use, including sound effects to short phrases like "Good Job!"



Display: Gives you control over the 100 x 64 pixel dot matrix display on the face of the NXT. It allows you to display or clear any one of the 95 included images or send text to any line of the eight line screen. The control panel even includes its own simple drawing

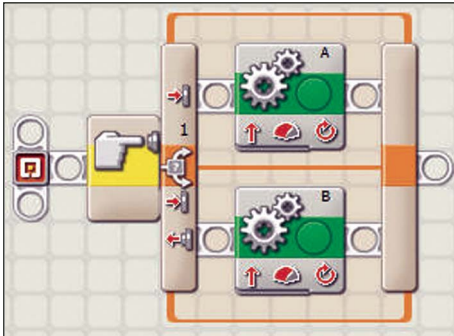


FIGURE 4. A short program using a Switch.

program for you to make your own images.

Wait For: This is actually the one menu in the common palette. It includes the “wait for” blocks (as seen in Figure 3) for Time, Touch, Sound, Light, and Distance. A “wait for” waits for something to happen, like a touch sensor being pressed or the lights in a room to turn on.

Loop: A loop is a common programming device that allows a portion of your program to repeat forever or until something happens. The loop can be controlled by a sensor as in “go forward until the touch sensor is pressed” or be set to repeat a certain number of times

before stopping as in “go forward until the touch sensor is pressed five times.”

Switch: The last icon in the common palette is another basic programming structure. The switch allows the robot to make a simple decision based on one of a number of things. In the example in Figure 4, motor A is turned on if the touch sensor is pressed in and Motor B if it is not.

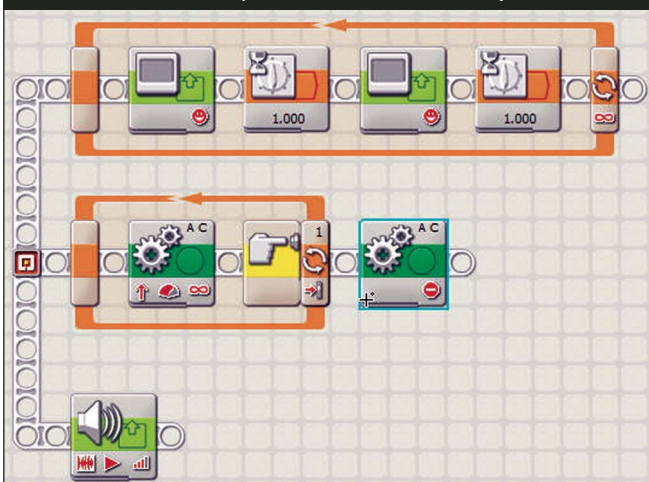
The Program Panel

Each program is contained in its own tabbed window making moving between programs easy. This will be especially handy in a classroom setting where several students are sharing one computer.

A program begins at the aptly named “starting point” by attaching icons to the center sequence beam. The top and bottom sequence beams can also be used for the same purpose allowing multiple parts of the program to run at the same time.

Figure 5 shows an example of a program with multiple tasks. This particular program puts a pair of eyes on the NXT display looking back and forth as it drives forward repeatedly yelling “Hooray!” while waiting for the touch sensor to be pressed. (Okay, so it isn’t the most practical program, but you have to admit that it’s fun!)

FIGURE 5. Top task: Displays alternating images at one second intervals. Middle task: Drives forward until the touch sensor on Port 1 is pressed. Bottom task: Plays a sound.

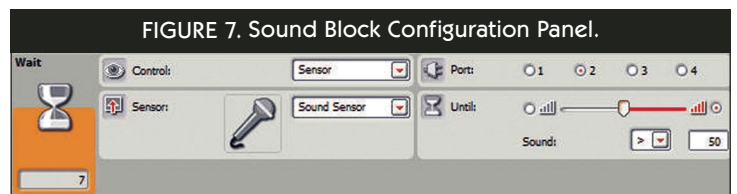
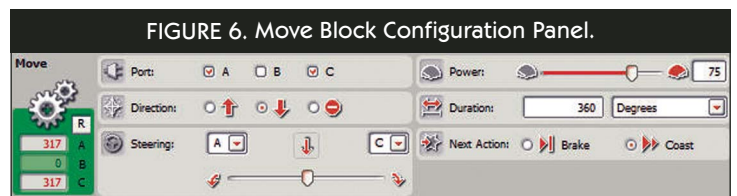


Individual blocks can be modified in the Configuration Panel located in the bottom left corner of the screen. Each time a block is selected, the panel changes to display the options for that block.

As you can see in the configuration panel for the Move block shown in Figure 6, we are running motors on ports A and C (old habits die hard) in the reverse direction. Just below — in the steering section — power can be shifted from one motor to the other, allowing you to fine-tune your turns. Overall, power is controlled via a similar slider and is much more sensitive and, therefore, ultimately more useful than it is on the RCX. Duration can be controlled by Degrees, Rotation, and Seconds, or set to Unlimited. You can even control whether the motor brakes or coasts to a stop when it’s finished running.

This is all great stuff, but the feature that I was most excited to see was the live motor readout in the green box on the far left. Now that every motor has a rotation sensor built in, we can look at the rotational state of the motors from inside the program — a handy new feature that will make programming specific rotation values easier. The red numbers indicate it has been going backwards, while black would indicate forward. As you will see in the following panels, this same live readout is used for a variety of programming blocks.

I obviously don’t have room to



take you on a tour of all the configuration panels, but Figures 7 through 10 show a few others you might find interesting.

The great thing about the “Wait For” panel is that if you change your mind and want to swap out a sensor somewhere in your program, you can simply use the sensor pull down menu to select any of the other sensors. As long as you still want a Wait For, you’re good to go with no need to rewire in a new block.

Downloading and Diagnostics

With our program written, it is time to download it to the NXT. This can be done through a USB cable or through a Bluetooth connection. Downloading a program is done through the Controller (see Figure 11) located in the bottom right corner of the programming window. Most of the buttons are self-explanatory, but two of them need a bit more explanation.

The first of these is the “Download and Run Selected” button. You can now select a portion of your program and run it in isolation, making the task of finding out why your little robot keeps driving off the edge of the table instead of backing away from it a whole heck of a lot easier. Yes, that’s right kids! Debugging nirvana! Say it with me – Sweet!

To the left is the button that brings up the NXT window that’s shown in Figure 12. The NXT window consists of two tabbed panels: Communications and Memory. The Communications window is where you connect with your NXT brick, be it by USB cable or Bluetooth. Once a connection is established, you can check your firmware version, battery levels, free memory, and even rename your brick. As you can see, I have named mine Pickle. Why? Because I can – that’s why! The little white Enter but-



FIGURE 8. Ultrasonic Block Configuration Panel.

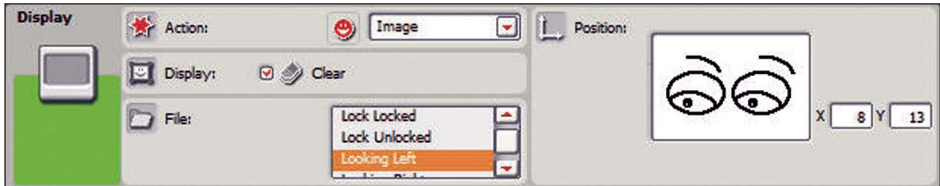


FIGURE 9. Display Block Configuration Panel.



FIGURE 10. Switch Block Configuration Panel.

ton to the right of the name downloads it to the brick.

Refer to Figure 13. The memory panel displays a memory map of what’s inside your NXT. The memory map to the left is color coded to show you how much of each type of file is filling up memory. Clicking on the link next to each color coded section changes the list to the right. If you’re running out of room, this is the place to come to delete that rarely used crud your

little brother downloaded when he was committed to building a lifesize LEGO C-3PO.

If you meticulously work your way through each section deleting

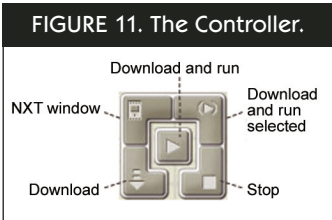


FIGURE 11. The Controller.

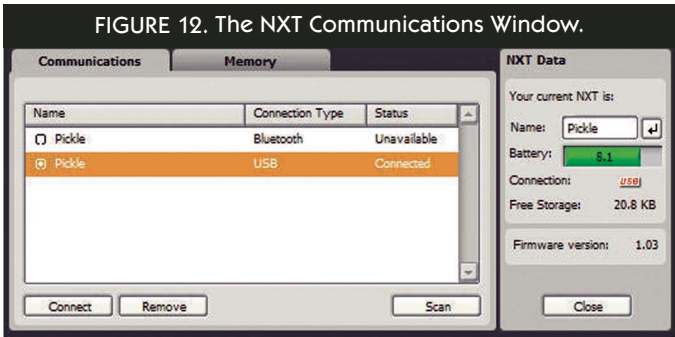


FIGURE 12. The NXT Communications Window.

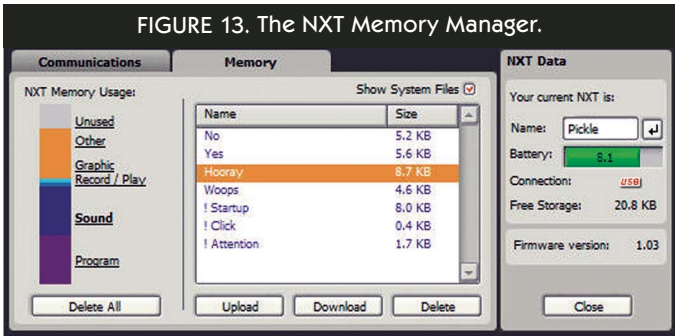


FIGURE 13. The NXT Memory Manager.

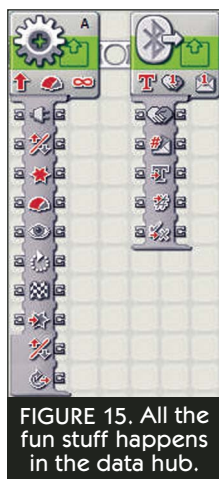


FIGURE 15. All the fun stuff happens in the data hub.

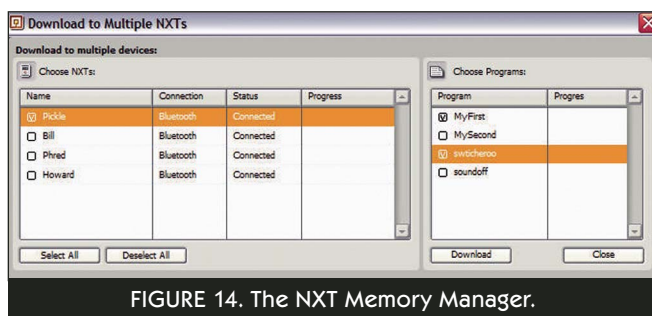


FIGURE 14. The NXT Memory Manager.

everything, you can free up almost 131K of memory. That's more than enough room to program that hexapod walker you've been thinking of building. To get back it all the default files simply download the firmware again.

Bluetooth Set Me Free!

Going wireless using Bluetooth is pretty easy and can begin from either the NXT software or the brick itself. One brief exchange of secret passcodes between the brick and your computer and you're connected. You are now free to exchange data with your robot from across the room.

One of the cool new features you'll find in the education version of the NXT software is the ability to download to multiple NXTs at once. This is a great gift to teachers who will no longer have to spend precious time downloading sample programs to multitudes of little robots one at a time.

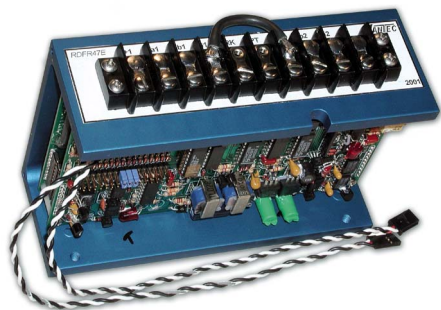
All said and done, it's a pretty nice piece of software that has taken some of the best elements from its predecessors and other popular software programs of the day combining them into a package that will make programming the NXT fast and fun.

Well, I think that about covers it ... what? What's that you say? I forgot to talk about the Complete or Custom Palettes and these thingys (Figure 14)? I didn't forget — I just don't have room to do it justice. That's a whole article in itself, maybe two, and I'll be back in August with more. Until then, you can check out the Mindstorms Education NXT blog at <http://legoeducation.typepad.com/> for more information.

The educational version of NXT Mindstorms can be pre-ordered from www.legoeducation.com and the retail sets can be pre-ordered from www.lego.com

Until next time, have fun! **SV**

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LEGO Mindstorms NXT Software v1.0 Minimum System Requirements

General

- 256 MB of RAM minimum (512 MB recommended)
- Up to 300 MB of available hard-disk space
- XGA display (1024 x 768)
- One available USB port
- CD-ROM drive
- Compatible Bluetooth adapter (optional)¹

Microsoft Windows

- Windows XP Professional or Home Edition with Service Pack 2
- Intel® Pentium® processor or compatible, 800 MHz minimum (1.5 GHz or better recommended)

Apple Macintosh

- Apple MacOS X v. 10.3.9 or 10.4
- PowerPC® G3, G4, G5 processor, 600 MHz mini-

um² (1.3 GHz or better recommended)

¹ Supported Bluetooth software include Widcomm® Bluetooth for Windows newer than v. 1.4.2.10 SP5 and the Bluetooth stacks included in Microsoft Windows XP with Service Pack 2/Apple MacOS X 10.3.9 and 10.4.

² The LEGO MINDSTORMS NXT Software is currently available for Intel-based Macintosh systems using Rosetta emulation. A universal update which will run native on Mactel systems will be available soon. While LEGO Mindstorms NXT Software is using the Rosetta emulator, Bluetooth functionality will not be available.

COMBAT ZONE

PARTICIPATION

World Class Driving

● by Wendy Maxham

Awise man once told us "LTFD." This man — Dave Calkins — spent hundreds of hours judging combat robot matches and has watched more fights than probably anyone else in the world. What is LTFD, you ask? It means "Learn to freaking drive!" Building a robot is only part of the challenge. If you don't learn to drive your bot, you aren't likely to put on a good fight during a competition.

Driving is one of the most important aspects of robot combat. In the robot community, you often hear that a well-driven, poorly-built robot can beat a badly-driven, well-built bot. When you have good control of your robot, you can use your robot's strengths against your opponent's weaknesses. Good driving can get you out of trouble or keep you from getting into trouble in the first place.

Driving practice helps you to learn what your robot is capable of. Each robot — even though they may look similar — drives different-

ly. We spend time with each robot test-driving it to see how it reacts. When you know what your bot can do, you don't have to think about it in the arena. Outside of the arena, my husband Matt thinks too much. But inside the arena, it's mostly action and reaction. While watching a video from a recent exhibition, Matt remarked that he was thinking about his driving rather than just reacting. As a result, Sewer Snake took a couple of big hits from Megabyte that luckily weren't fatal.

When Matt was giving me driving tips for my first competition with our Lightweight Wipe Out, he said to imagine you're sitting on the top of the robot. That way you're not thinking about left and right, especially when the robot is moving towards you. If you are mentally on the robot, you know which way to steer.

Matt likes to practice

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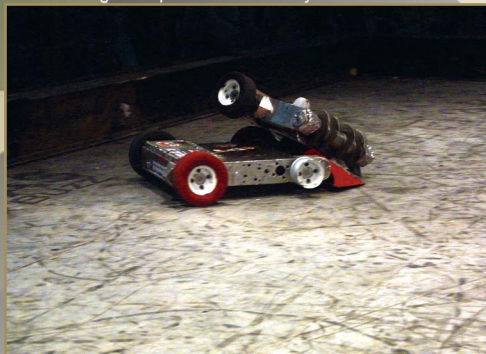
Product Review

27 *Copal 60:1 Gearmotor*
by Kevin Berry

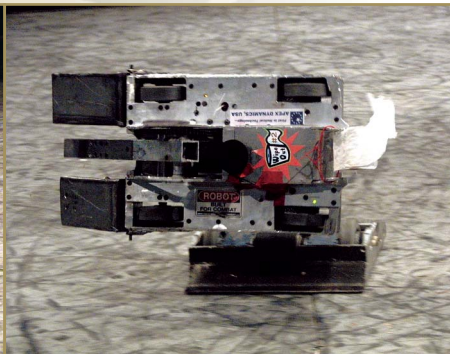
Warning
Restricted Area
Robot Combatants Only

This installation has been declared a restricted area according to the Secretary of Robotic Defense. Unauthorized entry is prohibited.

All persons and robots entering this area do so at their own risk.



MW Devil's Plunger loses a tire but can still push around Angry Asp.



LW Wipe Out #2 gets knocked around by Joe 2.0



HW Sewer Snake drives Megabyte to the wall.

hard with the bots to simulate battle conditions as much as possible. If the bot can't take it in the driveway, how is it going to survive in the arena? We have found weaknesses — sometimes the day before a competition — which we were able to fix before getting into the arena. If we hadn't test-driven the bots, we would not have encountered the problems until we were in the arena and would most likely have lost a fight.

One of Matt's favorite practice moves is — what he calls — the

"James Bond turn." He drives the bot forward in a straight line, and then spins 180-degrees so the bot is going backwards along the same line. Spin and repeat until you run out of space, always trying to keep the momentum of the robot on moving in the same direction.

One of my favorite practice techniques is from Grant Imahara's book *Kickin' Bot: An Illustrated Guide to Building Combat Robots*. Mark out a square and then drive the robot as close to the edges of the square as possible. Start out slow, then go faster and faster until you can run along the edges of the square at full speed. And don't forget to drive the square in both directions so you know how to turn both ways.

When Matt was younger, he was involved in competitive horse show jumping. His trainer's favorite motto was "anyone can jump high, but it's hard to jump well." With that, she meant you win in the preparation. It's all about practice, practice, practice. Robot combat is a combination of skill and luck, but

Team PlumbCrazy has found that the more we practice driving, the luckier we get.

Driving is not just practice; it's also a function of design. Matt grew up four-wheeling, so his designs are all about mobility — they're more fun to drive that way, too! Our heavyweight Sewer Snake is a six-wheel drive robot with an aluminum frame — three of the four sides are vulnerable. The key to Sewer Snake's success is keeping the weapon to the opponent and a powerful drive system. Sewer Snake is proof that a fight can be won with a strong drive system and good driving against big weapon bots. Winning isn't everything, but when you win, you get to keep fighting, which is more fun than packing up and going home. Plus, with an agile bot and creative weapon, you can put on a really cool show! **SV**

Wendy Maxham is half of Team PlumbCrazy with her husband Matt. Team PlumbCrazy started fighting robots in November 2002 and has fought in 18 competitions and three exhibitions for a total of 204 fights. Matt designs and builds the robots, and drives Sewer Snake, Devil's Plunger, and Angry Asp.

Wendy Maxham with National Champion Heavyweight "Sewer Snake."



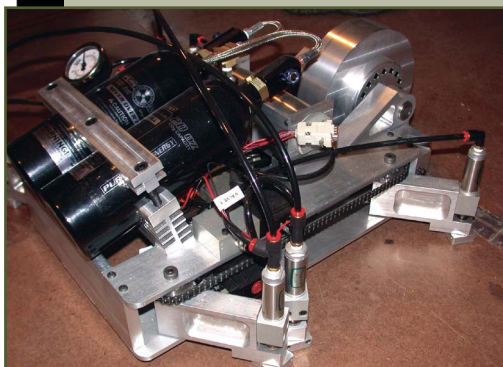
PNEUMATIC SYSTEM SAFETY

● by Eric Stott

Pneumatic systems can be extremely useful in many areas of robotics, as they provide many possible advantages over other types of actuation. That said, it is of utmost importance that these systems are used safely. In a pneumatic system, things happen very quickly, and only with a full understanding of

the principles involved can you properly protect yourself and others.

This article will attempt to give you a generalized understanding of these principles, but every specific situation will vary, so please do your homework! One cannot overlook the value of an experienced eye. If at all possible, find someone with prior



experience to review your system throughout the design and construction phases; it will save you time and frustration in the end.

Pneumatic systems can be dangerous, in part because of the potential for extremely rapid failure of components involved. *Never, ever* exceed the recommended ratings for any component in a pneumatic system. The manufacturer is required to go through extensive testing of their parts to ensure that they meet and exceed the ratings that they give the user to work with. They know their own product best.

System Specifics

Let's get a bit into specific components for a typical system. To begin with, you will need a source of gas (just come to our house!). In mobile applications, this is generally a compressed gas cylinder. The most popular types used for smaller robots are paint ball cylinders. All modern paint ball cylinders come with a burst disc in the neck of the cylinder. This is to prevent over-pressurization and explosion of the tank. If the temperature of the tank rises, the pressure also rises. Motors, batteries, and electronics can get really hot. Improper storage of the tank — such as in a hot car on a summer day — can also be dangerous.

If the pressure does get too high, the disc will burst, relieving the pressure in the tank and stopping the metal from turning into high-speed shrapnel. Do not attempt to defeat the burst disc!

After the source tank, you will want a valve so that you can shut off all pressure to the system. This is akin to the main power disconnect in an electrical system. In addition, you will want a second valve after the main shutoff which vents to the atmosphere. This is so that you can de-pressurize the system without venting the entire tank. Make both of these valves easy to reach, without putting any portion of your body in the path of moving or pinching objects.

Work Under Pressure

Although some people run their system at full bottle pressure, the majority of systems out there employ some degree of pressure regulation to bring the full gas pressure in the tank down to a working pressure. This is a popular route, as finding cylinders, valves, etc., to work at high pressures can be difficult.

When connecting the tank and main shut-off valve to the regulator, be sure to use appropriate rated lines. For paint ball type systems, this is easily accomplished with stainless steel braided lines. The vent valve mentioned earlier should be placed after the regulator so that the entire low side can be vented. Any gas remaining on the high side of the regulator will flow through the regulator as the pressure drops, and also be vented.

It is a good idea to place a pressure gauge after the regulator. Not only will this help in setting the regulator to the correct position, but it can indicate problems in the system. These gauges are generally not accurate over their entire scale, so try to pick one with approximately double the pressure you intend to measure.

The last safety specific device you want in the system is a pop off valve. Much like the burst disc on the supply tank, the pop off valve vents excess pressure from the low side. These can be purchased in specific pressure values, or as an adjustable type which you can set with a gauge and adjustable regulator. Unlike the burst disc, these valves will reset once the overpressure condition has been relieved.

The Right Stuff

When choosing valves and cylinders ensure that the parts you choose have appropriate ratings. This does not only apply to pressure ratings. Sometimes cylinders will be rated for multiple media or for specific media. You cannot substitute one rating for another. A 3,000 psi hydraulic rating

is not the same as a 3,000 psi air rating! Hydraulic fluid is an incompressible fluid, but air is very compressible and, as such, must be treated differently. In addition, the seals used in a cylinder or valve may only be appropriate for one particular fluid. CO₂ can cause certain seal materials to become brittle (due to its low temperature), so choose a seal of the correct type for what you're using.

Don't Roll Your Own

Whenever possible, use off-the-shelf parts. As stated previously, the manufacturer spends an enormous amount of time and money designing and testing their components. If you absolutely need something that doesn't exist, and can't change your design to suit an off-the-shelf part, you will want to follow a similar test procedure as the manufacturer does.

Custom-made parts need to be checked for safety, usually through a "hydro-test." In this test, a part is subjected to pressures in a controlled environment to determine at what point it fails. While this testing is not terribly expensive, it does add to the overall costs, as well as requiring you to machine more than one custom component. To find someone to "hydro-test" components, you can try asking your local welding gas supplier who they use. Welding gas cylinders need to be "hydro-tested" on a regular basis to maintain certification. Be aware that some hydro shops may not be terribly receptive to testing custom-made components.

Inspect to Detect

When operating a pneumatic system, several precautions must be taken. Prior to turning anything on, inspect the system for damage. Cracked or damaged hoses, dented tanks or cylinders, or any other physical damage can cause a catastrophic failure. Don't take chances here! If something doesn't look right, it probably isn't. The potential damage or personal injury that can result from a

failure is never worth the time it would have taken to do it properly.

If the robot is remotely operated, check that your radio or other control system is functioning correctly before turning on the pneumatics. As stated previously, put your valves in an easy-to-access location, away from anything that could possibly actuate when pressure is applied to it.

If this is the first time running the system, use the lowest pressure that you can to test the actuation. Many valves have a minimum pressure requirement; use this as the baseline. This will also help to show where any leaks might be. If your design allows, test the system outside the robot first, and mount it securely to a large stationary object.

Deactivation

When deactivating a pneumatic system, again inspect for damage that might have occurred during use. If there is any chance that the higher pressure components have been damaged, proceed with extreme caution. At this point, it is advisable to vent all the gas from the source tank; open up the atmosphere ventilation valve and the source tank valve. Leave them open for some time, as rapidly expanding gas can get so cold that it freezes to solid. If you close the valves too soon, the gas will unfreeze, then expand and re-pressurize the system.

Summary

These general guidelines will get you well on your way to operating a safe pneumatic system in your robot. If this system is going to be used in a competition, be sure to check with the organizers before you begin construction, as particular rules may vary. If you do plan to use pneumatics, research all aspects of the system and budget accordingly to make the safest system possible, composed only of reputable components. As previously stated, there is no amount of money worth the risk of injury to you or someone else. Be safe! **SV**

EVENTS

Upcoming (all RFL National qualifiers)

ComBots — *ROBOlympics/Tetsujin* 2006, San Francisco, CA, 6/15–18/2006 (www.combots.net). Over 130 combat bots registered, plus 60 non-combat, in the third year of this mega event. Dave Calkins and a team of veteran organizers hold one of the world's top robotic competitions, and all the major names in combat robotics converge for the best in robot fighting.



War-Bots Xtreme — *WBX-III*, Saskatoon, Saskatchewan,

Canada, 7/22-23/2006 (www.warbotsxtreme.com). Canada's BIGGEST combat robot tournament. Weight divisions from Ants to Heavy Weights, plus Bot Hockey.



Team Think Tank — *SNF Qualifier*, Pasadena, CA, 7/22/2006 (www.teamthinktank.com). This event includes Fairy, Ant, and Beetle Weight classes.



TECHNICAL KNOWLEDGE

Using Two Speed Controllers to Control One Four-Pole Motor

● by John Kruse

If you'd like two speed controllers to share the current requirements for the motor, then follow this procedure for separating the brushes in a four-pole motor. The motor I used is the National Power Chairs NPC 74038, and my speed controllers are IFI Victors. At the time of this writing, this particular motor is no longer available from NPC, but this method should work for any four-pole motor that meets these requirements:

- They must share a common power source.
- They should share a common signal source.

- The speed controller H-bridge must be configured so that one leg is "full on," and the other leg is modulated for PWM control.

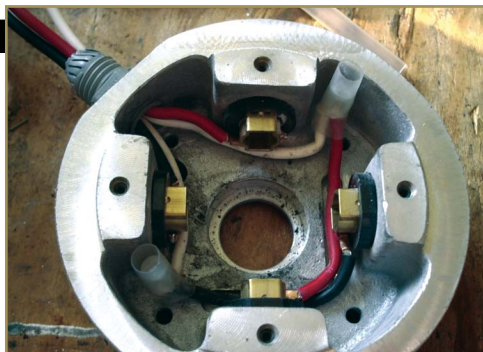
- The motor must be wound in a "wave" pattern; there is a coil from each commutator segment to the next. Most modern motors are done this way.

- The motor's magnets and brushes must be arranged to be alternating polarity; going around the circle, there would be a + brush, then a - brush, then +, then -.

First, mark the orientation of the cap on the motor body so you can

get it back in the original location, then remove the brushes. Remove the four nuts that hold the endcap and gently and evenly pull the cap off. Upon turning it over, you will see the brush wiring.

The brushes are connected in series on each wire. In the photo, you can see that the red wire is connected to the flag clip under the brush at the three o'clock position. The red wire then runs under the brush at the six o'clock position and connects to the brush at the nine o'clock position. The "flag clip" is the brass connector that the wire is crimped into. In this motor, I left the long wires connected and cut the junction between the brushes, leaving the short piece of wire that connected the two brushes to attach a new wire to. The new wires are attached to the brushes at nine o'clock and at six o'clock. Make a good mechanical connection and insure nothing



touches the case.

Now to Test

Divide the leads into two red/black pairs. Test by momentarily touching one pair to a 12 V battery; see which way the motor spins. Momentarily touch the other pair to the 12 V battery; ensure that it spins the same way. Then hook the speed controllers up. They only accept input power in one polarity; having this backwards will kill them. Hook up the RC leads; you will probably need the inline buffer. Hook one set of leads

to the first speed controller (leave the other disconnected for now). Test using the radio to see that it works, and to see if "forward stick" creates "forward motion." If necessary, reverse the leads at the output of the victor.

Disconnect that set temporarily and hook the other set to the second Victor; use the same polarity as you ended up with on the first Victor. Test for motion and to see if forward equals forward.

For more information, go to www.ifirobotics.com or www.npcrobotics.com **SV**

PRODUCT REVIEW — Copal 60:1 Gearmotor • by Kevin Berry

This little motor is the workhorse of the Antweight set. There are several gear ratios available for Copal motors, but I've always found this to be the best balance of torque, speed, and size. Rated at 71 oz-in of torque at 12 volts, it's 1.5" long, and 5/8" in diameter. It turns at 410 RPM. I use 1.75" foam wheels, and either prop adapters or hubs, and generally mount it with wire ties.

There are custom mounts available from various suppliers. The 30:1 version has a reputation for stripping gears, but the 60:1 version seems to be bullet-proof. Supporting the motor shaft at the output, or the opposite side of the wheel, protects the bearing and assures long life. Pictured is antweight Babe The Blue Bot, which uses four of these

motors for tons of pushing power. Data and photo courtesy of www.robotcombat.com **SV**



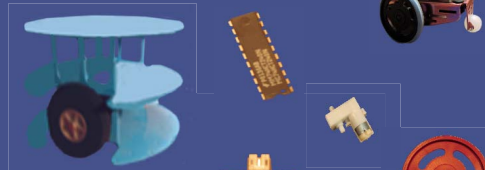
Legendary Robotics Antweight Babe The Blue Bot uses four 60:1 Copal Gearmotors coupled to 1.75" foam wheels.



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EVENTS CALENDAR

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Summer is here and the robot events keep coming. What sort of robot contest is more appropriate to summer weather than robotic lawn mowing? If you're near Dayton, OH, check out the ION Autonomous Lawnmower Competition. Prefer swimming to mowing in the hot weather? Maybe your robot would, too. We've got both an ROV and AUV contest coming up this summer. The Vancouver Robotics Club has more summer weather tie-ins with their BEAM events for solar-powered robots.

Do you know of any robot competitions I've missed? Is your local school or robot group planning a contest? If so, go ahead and send an email to editor@robots.net and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, please send that, along with the URL, so we can tell everyone else about it.

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net: <http://robots.net/rcfaq.html>

— R. Steven Rainwater

June

- 1-3 ION Autonomous Lawnmower Competition**
Dayton, OH
Autonomous lawn-mowing robots entered in this contest for university students will be judged on the speed and accuracy of their mowing.
www.automow.com
- 3 RoboBombeiro**
Polytechnic Institute of Guarda, Guarda, Portugal
Firefighting robot contest.
www.estg.ipg.pt/roboBombeiro
- 2-4 Eurobot**
Catania, Italy
Involves black balls, white balls, and holes — robots match off two at a time.
www.eurobot.org
- 10 UK National Micromouse Competition**
Technology Innovations Center, Birmingham, UK
Micromouse builders compete for the coveted Brass Cheese. Try to make it to this Micromouse event.

These are amazing little robots.
www.tic.ac.uk/micromouse

- 10 Vancouver Robotic Games**
BCIT Campus, Burnaby, British Columbia, Canada
Line following, advanced line following, BEAM Solaroller, BEAM Photovore, and a walker triathlon.
<http://vancouverroboticsclub.org/>
- 10-12 AUVS International Ground Robotics Competition**
Harrison Township, MI
University-built autonomous ground robots navigate an outdoor obstacle course.
www.igvc.org/deploy/
- 14-20 RoboCup Robot Soccer World Cup**
Bremen, Germany
All the usual Soccer events: small, mid, humanoid, and AIBO. Also a NIST rescue robot contest. In addition to these events, the RoboCup @Home competition will be held in conjunction with the World Cup this year.
www.robocup.org/
- 16-18 RoboGames**
San Francisco State University, San Francisco, CA
The robot competition formerly known as Robolympics is back. It will have more robots and events than I can list here. Visit the website.
www.robogames.net/
- 23-25 MATE ROV Competition**
Neutral Buoyancy Lab, NASA Johnson Space Center, Houston, TX
Student-built ROVs must locate and retrieve objects of varying size and shape.
www.marinetech.org/rov_competition/
- 24 Mobile Robotics Software Challenge**
Portland, OR
Computer and software ride on a provided robot and report while on the path. Also known as the egnellahC dnarG APRAD because it's like the DARPA Grand Challenge in reverse.
www.mobilerobot.org/MRSC.htm

July

7-10 Botball National Tournament
Norman, OK
 Teams compete with autonomous robots built from standardized kits.
www.botball.org

16-20 AAI Mobile Robot Competition
Boston, MA
 This long-standing competition for autonomous robots typically includes the Robot Challenge, in which robots navigate the conference center; Robot Rescue, in which robots must locate injured humans in a disaster area; and Hors d'oeuvres anyone? in which robots must serve and interact with humans
www.aai.org/Conferences/National

17-21 K'NEX K*bot World Championships
Las Vegas, NV
 Includes three events: Two-wheel drive K*bots (autonomous), Four-wheel drive K*bots (autonomous), and Cyber K*bot Division (R/C)
www.livingjungle.com

27 AUVS International Aerial Robotics Competition
US Army Soldier Battle Lab, Fort Benning, GA
 Flying robots are required to complete a fully autonomous ingress of 3 km to an urban area, locate a particular structure from among many, identify all of the true openings in the correct structure, fly in or send in a sensor that can find one of three targets, and relay video or still photographs back 3 km to the origin in under 15 minutes. And that's just one of three scenarios!
<http://avdil.gttri.gatech.edu/AUVS/IARCLaunchPoint.html>

August

2-6 AUVS International Undersea Robotics Competition
US Navy TRANSDEC, San Diego, CA
 Autonomous underwater robots must complete a course with various requirements that change

each year.
www.auvsi.org/competitions/water.cfm

4 Elevator:2010 Climber Competition
Mountain View, CA
 Autonomous climber robot must ascend a 60 meter scale model of a space elevator using power from a 10 kW Xenon search light at the base.
www.elevator2010.org/site/competitionClimber2005.html

September

1-4 DragonCon Robot Battles
Atlanta, GA
 Radio-controlled vehicle combat held in conjunction with the annual DragonCon science fiction convention. Besides watching the machines destroy each other, you can meet dozens of interesting folks including Robert Asprin, Yvonne Craig, George A. Romero, and Mark Goddard.
www.dragoncon.org

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MATE ROV Competition

The Marine Advanced Technology Education (MATE) Underwater Robot Challenge

When we think of famous robots, we all too often think about what a robot looks like, rather than what the robot can do. If we were to judge robots (real, not science fiction) based on their achievements, the Mars rovers would certainly top the list. But there's a group of robots that undergo greater extremes than the Mars rovers, and yet are too often forgotten — underwater Remotely Operated Vehicles (ROVs).

The most famous of these is the Argo — the bot that found and explored the wreckage of the Titanic, the Bismarck, and other lost ships. Yet, these robots have to rely on tethers for communications rather than wireless systems, and put up with the incredible pressures of deep-sea exploration.

But the Argo is just one such robot. The Monterey Accelerated Research System (MARS) is an underwater observatory that will soon be deployed in California. It will be cabled to the surface with both power and data lines so scientists can run multiple experiments using instruments that stay underwater. The MARS central node has two parts: a removable inner

module that contains all of the wiring and electronics, and an outer metal frame that protects the node from damage due to fishing nets. The node will be capable of providing up to eight "science ports" that can deliver power and facilitate communications to other instruments.

MARS needs vehicles to deliver modules to those eight science ports, and that's where the contest comes in. MATE created the ROV Challenge, which is a competition where students design underwater ROVs that are capable of finding a box that's similar to the actual module. From there, they have several different tasks to perform. The event has three classes open to students in middle school, high school, and college.

The Missions

There were two different classes of robots at the recent event in Monterey: Ranger and Scout. There is also a college level competition Explorer, which is almost identical to the Ranger event, but with much greater power limitations.

Both events include three sections: a presentation, a poster, and the actu-

al robot performing the assigned tasks. Presentations and posters were fairly standard for high school events, focusing on what the teams had learned both about building the robots, as well as the actual environment they were emulating (in this case, deep-sea instrument placement and the environments that they'd be monitoring).

Scout Class

The Scout class is an entry level event that targets middle schoolers who want to get their feet wet in robotics (you didn't think I could pass that up, did you?). Students needed to complete two missions: Ocean Census and Deep Sea Observatory.

For the first mission, Scouts were asked to retrieve a number of weighted replica fish floating just above the pool bottom, replicating how scientists can gauge fish populations. In Deep Sea Observatory, three PVC "electronics packages" are dropped into a line of milk crate "nodes" at the bottom of the pool. Scouts piloted their ROVs by looking directly at them and their targets as they traversed the bottom of the pool, and exercised teamwork through communication between the

“But there’s a group of robots that undergo greater extremes than the Mars rovers, and yet are too often forgotten — underwater Remotely Operated Vehicles (ROVs).”



Photo 5



Photo 1

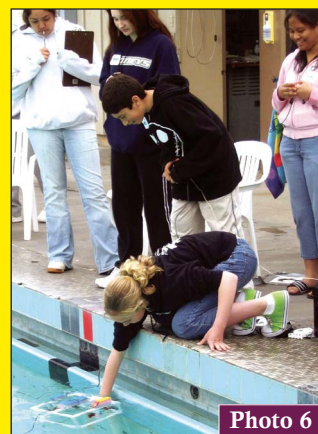


Photo 6



Photo 7

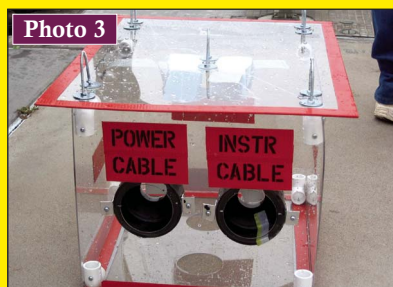


Photo 3



Photo 2



Photo 8



Photo 4

PHOTO 1. Some teams drove their robots using traditional electronic boxes ...

PHOTO 2. ... while others could drive via computers.

PHOTO 3. The “electronics module” that Ranger teams needed to drop off beneath the waves.

PHOTO 4. A Ranger ROV maneuvers toward the platform, under the watchful eyes of a referee (nice job, if you can get it ...).

PHOTO 5. The Aptos High School robot used a huge array of electronics.

PHOTO 6. A Scout team retrieves their robot, now filled with fish.

PHOTO 7. Members of the Jesuit High team connect their ROV and prepare for launch.

PHOTO 8. Team HCN won the Guts & Glory prize for spending no money on their robot — winning a much needed gift certificate to OSH.

MATE ROV Competition

pilot and the team members in charge of the tether.

Ranger Class

The Ranger class compounded the tasks into something a little more challenging than the Scout class. Teams were asked to simulate completion of a "central node." They were to locate the undersea fishing-trawler-resistant frame, bring a simulated electronics module that fit snugly into the frame down to the survey sight under the sole power of the ROV, and connect a simulated power cable to the electronics module. The second task involved pulling a pin to release a simulated electronics module to the surface. Unlike the Scout class, Ranger pilots were not allowed to look directly at the ROV as it related to the target within the pool — they had to operate backs-to-the-water, driving strictly by the view afforded by the ROV's camera as displayed on a monitor.

Sounds simple, right? It's not. Think of this — you're on your way down to the bottom of the ocean,

guided by a first-person camera with only a small, limited field-of-view to guide you. You have to use all the fine motor skills you can muster to finish the task, with only the aid of whatever gripping, grabbing, or hooking apparatus you have in view of your camera. No one can give you an overview of where you are in relation to your objective. You need to use everything you know about spatial relationships, you need to know the flaws and advantages of your vehicle by heart, and how to improvise in a pinch. You've relied on your teammates to design you a vehicle that can adapt well to any set of circumstances, and now the pressure's on.

Some teams — such as St. George's School from Vancouver — had multiple cameras relaying information back and forth as the ROV completed its task, with the primary one in the prow, one angled from above the center of the ROV, and the third ingeniously floating on the surface along with the tether.

Teams had 20 minutes to complete each task. For most teams, using their machines was a trial by fire — they

hadn't been able to test in field conditions, so they had to go for it and hope for the best. Some teams were so excited that their machines actually floated that just getting their ROV launched was a major victory.

ROVs often got turned around in the water, so knowing which way they were going was sometimes very difficult. Team Hermisenda Crassnicornis Nudibranchs (or HCN) was the only group that actually relied on adding any additional sensors besides the camera. A cheap underwater compass was attached to the ROV at the bottom of the camera's field-of-view, which allowed them to always know their orientation.

HCN also demonstrated admirable improvisational engineering, motivation, and teamwork — they were four friends from three different schools with no money, no teacher, no tools, and no mentor. They built their ROV in their spare time with free or salvaged parts that they found (including the compass). Yet, they were the only team to have any sensors, and one of the very few with an active ballast system.

Only one or two of the 20 teams competing in the Ranger class used speed controllers — most teams had no way to increase or decrease the speed of the motors (usually bilge pumps). Once again, HCN came up with a very clever (yet, still free) solution to fine-tune steering (which was so important in trying to dock vehicles without oversteering). They used a kitchen light rheostat in line with the power to the propellers in order to reduce voltage to the motors, achieving very fine control of their steering with a simple turn of a knob! Not the best solution, but with no money for speed controllers, it sure beat most other teams who still only had on/off buttons. Somebody give these guys a scholarship!

Science and engineering events usually have a dearth of female contestants — not so here! Paradise High School — the overall winners — was a team comprised primarily of young girls, and there were several all-girl teams, as well. This is very

MATE ROV CHAMPIONS

ROVER CLASS:

(Salinas & Monterey, CA)

Overall Winner

- 1st — Paradise H.S. (Paradise, CA)
- 2nd — St. George's (Vancouver, Canada)
- 3rd — Jesuit H.S. (Carmichael, CA)

Mission

- Paradise High School

Poster Display

- Paradise High School

Engineering Evaluation

- Saint George's School

Harry Bohm "Sharkpedo" Award

- Aptos High School (Aptos, CA)

Team Spirit

- Monterey High School
- Jesuit High School [tie]

Guts & Glory

- Hermisenda Crassnicornis Nudibranchs

Judges' Choice

- Weber Institute (Stockton, CA)

SCOUT CLASS:

Overall Winner

- 1st — Pacific Grove
- 2nd — Buena Vista

Ocean Census

- 1st — Alpha Echo Girls (Buena Vista)
- 2nd — Pacific Grove
- 3rd — San Carlos

Deep Sea Monitoring

- 1st — Pacific Grove
- 2nd — Pacific Grove
- 3rd — Buena Vista

Design and Innovation

- 1st — Pacific Grove
- 2nd — Buena Vista

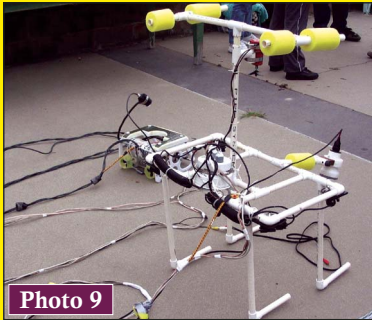


Photo 9

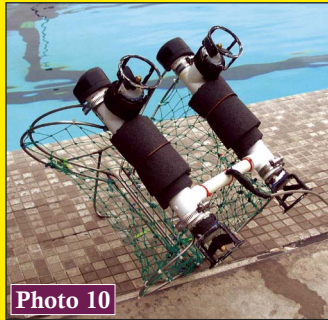


Photo 10

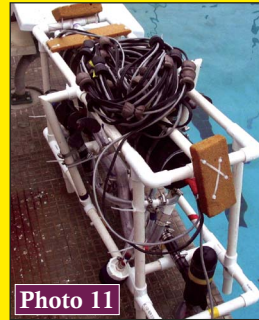


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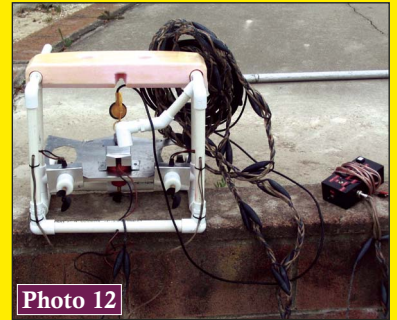


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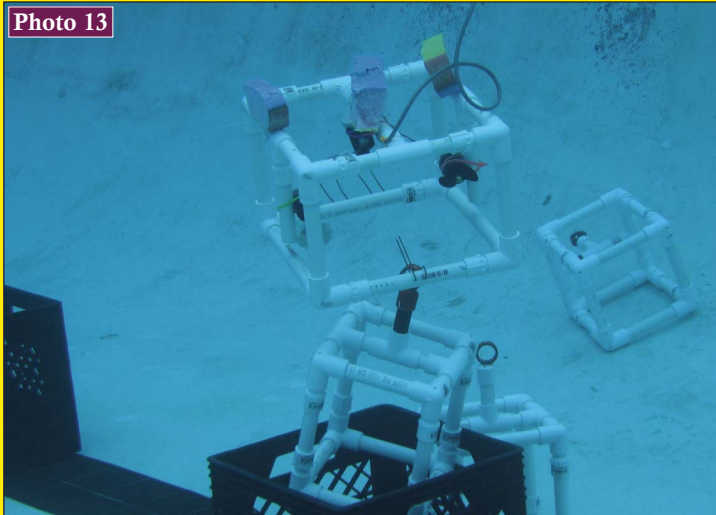


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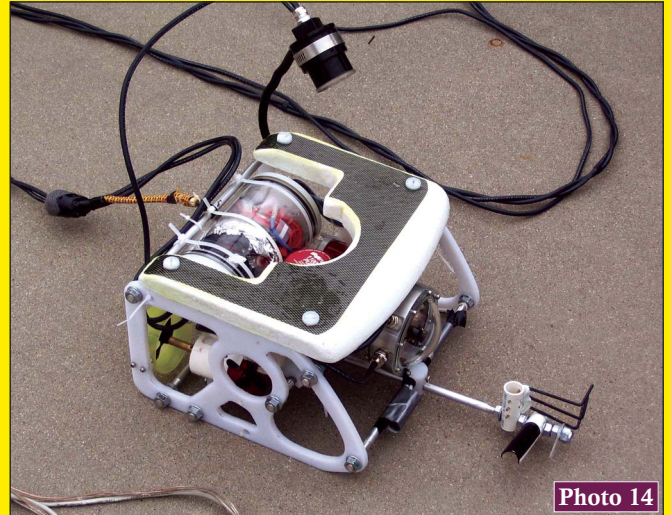


Photo 14



Photo 15



Photo 16

PHOTOS 9 through 12. ROVs come in many shapes and sizes.

PHOTO 13. A scout ROV drops off "electronics packages" into the milkcrate "nodes." Photo courtesy of Jenny Stock.

PHOTO 14. The Ranger ROV from Vancouver — note the second overhead camera for better accuracy in driving.

PHOTO 15. Monterey High prepares their Ranger class robot for the water.

PHOTO 16. Members of an all-girls team show off their ROV.

encouraging news!

The competition displayed the students' grasp of the many skills necessary to robotics — an understanding of a wide range of mathematic and scientific fields, the necessity of being an effective team player, the ability to explain your project intelligently, and the understanding of efficient form and design. Yet, it also presented a new problem for robot builders — building bots that are watertight

and pressure resistant.

Underwater Robot Events in 2006-2007

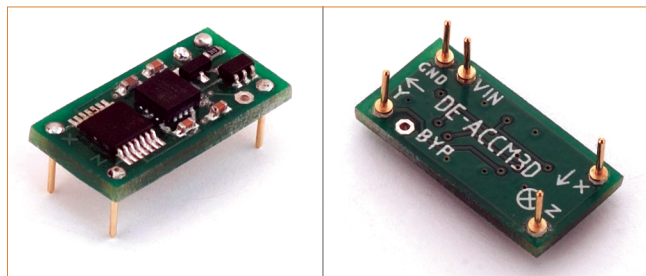
Most underwater robotics competitions are limited to high school and college students. There are three events remaining in 2006: the AUVS International Undersea Robotics Competition Aug. 2-6, 2006 in San Diego, CA; the Hawaii Underwater

Robot Challenge, Nov. 24-25, 2006 in Oahu, HI; and the MATE ROV Competition finals Jun. 23-25, 2006 in Houston, TX. If you're not a college or high school student, with some ingenuity and a borrowed pool, you should be able to do your own events. As the HCN team proved, you don't need a huge budget to build an underwater bot. I'd love to see you all build your own underwater bots and send the details in to *SERVO*! **SV**

NEW PRODUCTS

ACCESSORIES

The DE-ACCM3D



Dimension Engineering has just released a full-featured triple axis $\pm 3g$ analog accelerometer board: the DE-ACCM3D.

Triple axis accelerometers can measure motion in all directions and are used in robots, UAVs, self-balancing vehicles, and even in the game controllers of next generation console systems.

The DE-ACCM3D takes a miniscule accelerometer chip and breaks it out onto a five-pin board that is easy to handle and fits into a DIP-16 socket.

The product has an onboard 3.3 V LDO regulator, which allows great flexibility with operating voltages up to 15 V. The 3.3 V supply can also be used to power an external microcontroller. The regulator can be bypassed for operation as low as 2.0 V, for tiny hand-held applications.

A problem with existing accelerometer solutions is that their high output impedance can result in unreliable readings. Dimension Engineering has remedied this by buffering the signal on each axis, so they can accurately drive heavier loads or be directly connected to a microcontroller's ADC. DE-ACCM3D maintains a bandwidth of 500 Hz, making it suitable for sampling high frequency motion.

Reverse voltage protection, short circuit protection, and supply filtering have also been implemented on the DE-ACCM3D, so no external passives are necessary.

DE-ACCM3D is aimed at hobbyists, students, and prototyping engineers who need a quick and easy analog motion sensing solution. The introductory price is \$35.

For further information, please contact:

Dimension Engineering

Website: www.dimensionengineering/DE-ACCM3D.htm

CONTROLLERS & PROCESSORS

Modular OSMC Brain (MOB)

The MOB is a flexible high-performance microcontroller interface to the OSMC power controller offered by Robot Power. The MOB provides the interface between various command input sources and generates PWM signals to drive two OSMC boards. Powered by the Atmel ATmega163 processor running at 8 MHz, the MOB provides ample computing horsepower for driving the OSMC boards and interpreting and conditioning a range of input sources.

The MOB is the more sophisticated of two RC/OSMC interfaces offered by Robot Power. The other — the μ MOB — is much smaller, lower cost, and has fewer options.

The primary and original input sources for the MOB board are three standard hobby R/C signals. These signals conform to the R/C standard in use for many years in a large variety of products. Namely, a nominal 1.5 mS signal which varies in length from 1.0 to 2.0 mS. The pulse repetition frequency is in the 40-60 Hz range. The MOB software considers two of the input channels to be "drive" signals and converts them to a proportional PWM duty cycle on the OSMC outputs, optionally mixing the into together in a "throttle" and "steering" mode. The third channel is an "auxiliary" channel which is driven as a SPDT switch through and opto-isolation circuit. The auxiliary channel is intended to switch high-power loads in an on-off fashion through an external amplifier such as a relay or other power switching device.

The MOB software is written in C language using the free GCC compiler for the AVR family. It uses a real-time operating system called AvrX written and supported by Larry Barelo.

Since the MOB software is open source, all the MOB software source code is available in the downloads section of the site for inspection or modification. Also on the downloads page are links to the GCC compiler, AvrX download site, and the PonyProg programming software used to update the software in the MOB. All of this is freely available for commercial or private use without cost (commercial use of AvrX outside of the OSMC requires the permission of the author).

Robot Power offers the MOB in fully assembled units, kit form, and as a bare circuit board.

For further information, please contact:

Robot Power or Larry Barelo

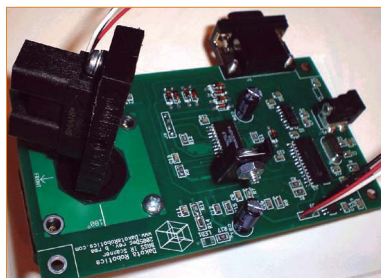
Website: www.robotpower.com or
Website: www.barello.net

SENSORS & CONTROLLERS

New Robotic Vision Systems and Stepper Motor Controllers

Dakota Robotics is now offering two new products: the Infrared Robotic Vision System and the Single Axis Microstepping Stepper Motor Controller and Driver.

Infrared Robotic Vision System



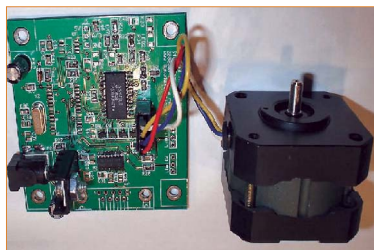
The BASS IR module scans a GP2Y0A02YK IR Long Distance Measuring Sensor over a 180° field-of-view. The BASS determines distance by measuring the analog output of the IR sensor and

outputs the distance in centimeters over a serial port to a BASIC Stamp or similar robot controller. Its overall range is approximately 20 cm to 150 cm. The scanner outputs 33 data points representing the range at 5.4° increments over a 180° arc giving your robot excellent data about its environment. This device works well for most "target avoidance" applications including combat competitions. The stepper motor is a .28A, 1.8° motor. The BASS IR scanner outputs range data over an RS232 interface. Range data is given in centimeters, in polar format.

Features for this product include:

- GP2Y0A02YK Sharp IR Sensor Included, range (20 cm – 150 cm)
- 33, 5.4° data points representing range to objects
- 1.8 degree, .28A bipolar stepper motor included
- Optical home switch for increased position accuracy
- Built-in translator
- RS232 control, 19200BAUD-n-8-1
- Approximately 30 scans per minute rate

Serial Microstepping Stepper Motor Module



The new STEP1 serial stepper motor module provides a complete motor control solution for robotic applications. The STEP1 features a microstepping motor driver with

an embedded serial motor which measures 2.5" x 2.625". The STEP1 was designed to allow rapid implementation of stepper motor solutions in products

that require automation.

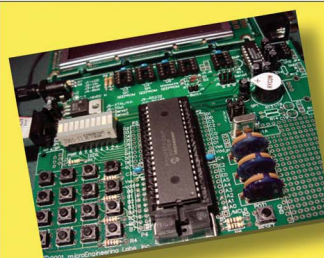
The module is suitable for driving bipolar stepper motors from 15-750 mA on 9-30 VDC power supplies. It operates in full-, half-, quarter-, and eighth-step modes that are software selectable. Extended software commands – which are intuitive and simple – have been implemented for extreme hackability. Other features include dual digital limit switch inputs and an analog limit switch input with a software selectable limit voltage. The analog input allows for a potentiometer position measurement when necessary. When a limit switch is triggered, the STEP1 reports the limit switch that was triggered by the serial port.

The STEP1 is easy and economical to operate; all you need is a serial cable and a terminal on a PC, MAC, or Linux computer. Using HyperTerminal for Windows allows full operation within minutes of receiving the STEP1. This module may also be connected to many robot controllers like the BASIC Stamp products. You can purchase the complete STEP1 module for the price of \$89 per unit, which includes the STEP1 control board, a size 17 bipolar stepper motor, and a 9 VDC power supply.

For further information, please contact:

Dakota Robotics

Email: support@dakotarobotics.com
Website: www.dakotarobotics.com



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MOBILITY



To The Maxx

PART 3 — Motor Skills

⇒ by **Chris Cooper**

For more information on this product, visit www.machinebus.com/emaxx

Last month, we laid the foundation of the E-Maxx control system. After adding a module for servo control and another for wireless communication, we can effectively operate the E-Maxx using a USB joystick from a PC.

The existing Traxxas electronic speed controller (ESC) allows us to drive the two E-Maxx motors in forward and reverse, but only at relatively high speeds. This makes it difficult to position the E-Maxx accurately, read sensors, and move in tight spaces. The ESC was designed for racing. But moving fast is not the same as going somewhere, and our robot will need to go places.

In this article, we will replace the ESC with two motor controllers, which are better suited for robotics because they are capable of fine-grained speed increments and have a greater overall speed range. We will also add a quadrature rotational encoder to monitor

the speed and direction of the E-Maxx. After these modifications, the E-Maxx will have the motor skills required for precise, controlled, and consistent movement about its surroundings.

Replacing the ESC With Motor Controllers

Before removing the ESC, we need to understand its current functions. First of all, it uses pulse width modulation (PWM) to regulate the 14.4 V supply going to the motors. A standard R/C servo signal is used to vary the power. Secondly, the ESC regulates the 14.4 supply voltage to provide 5 V of power to

the steering and shifting servos. So when we replace the ESC, we will create another 5-6 V supply to power the servos.

Using a second LM2940-CT 5.0 low dropout voltage regulator with a heatsink proves to be a viable solution to power the steering and shifting servos. It also keeps the electrically noisy servos isolated from our digital electronics. Each servo has a no load operating current of around 350-450 mA, which falls under the one amp limit of the LM2940.

Photo Above: The E-Maxx RC monster truck makes an excellent robotics base. Photo courtesy of Traxxas.

Figure 1. The schematic for power regulation that we will duplicate for powering servos.

Finding the right motor controllers to replace the ESC's motor control functionality took some investigation. I had a difficult time finding information on the motors supplied with the E-Maxx. The supply voltage is 14.4 V, but I also needed to know the maximum current draw.

A motor draws the most current when stalled or starting. One way to determine the stall current without a data sheet is to measure the resistance of the brushes and winding when stationary. Using a standard ohmmeter, I found the resistance to be 0.65 ohms. I calculated the maximum current draw of each motor from the two known values using Ohm's Law:

$$14.4 \text{ V} / .65 \text{ Ohms} = 22.15 \text{ Amps}$$

Based on these motor characteristics, I found the new Parallax HB-25 Motor Controller to be a great match. The most impressive feature of the HB-25 is its excellent power dissipation — a feature that the alternative controllers I researched lacked. The HB-25 incorporates a large, machined aluminum heatsink, thermally bonded to the motor driver circuit. Attached to the heatsink is a fan that draws air through holes in the heatsink to provide outstanding cooling.

In addition to the impressive thermal characteristics, the HB-25 features over voltage, over current, and over temperature protection circuitry and can be controlled using standard R/C servo signals.

Two HB-25s can easily handle the E-Maxx motors, accepting motor supply voltages from 6-16 volts and a continuous current of 25 amps. Since the HB-25 is controlled using standard R/C servo signals, I can still use the servo control circuitry described in the March issue.

Installing the two HB-25 motor controllers is straightforward. There are two mounting holes pre-drilled in the aluminum blocks. I drilled matching holes

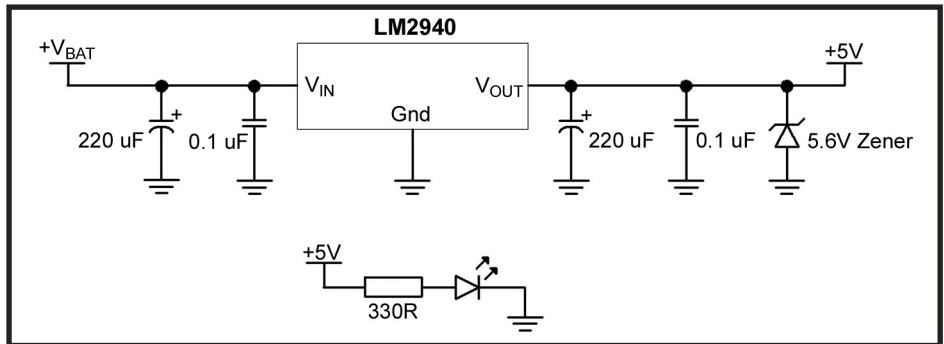


Figure 2. The Parallax HB-25 Motor Controller has an impressive thermal design to stay cool while handling the E-Maxx motors.

into the deck of the E-Maxx and fastened them using 4-40 screws. I wired the batteries, motors, and HB-25s using 14 gauge silicone wire, which is more flexible than plastic insulated wire.

I chose spade connectors to attach the wire to the HB-25's screw terminals, as opposed to ring connectors. Spade connectors make adding and removing connections easier than ring connectors, which would require removing the screw completely when adding or removing a connection. Check that the ends of the spade connectors do not make accidental contact with the fuse or

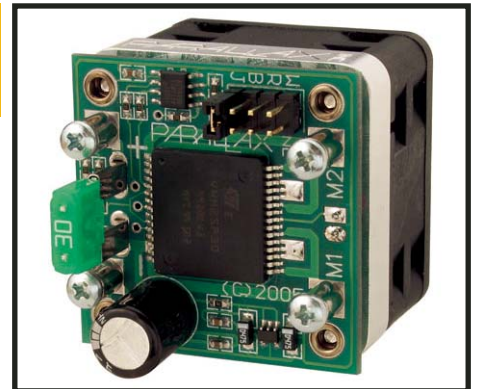


Figure 3. A pair of HB-25s mounted to the deck and wired to the Servo Module.

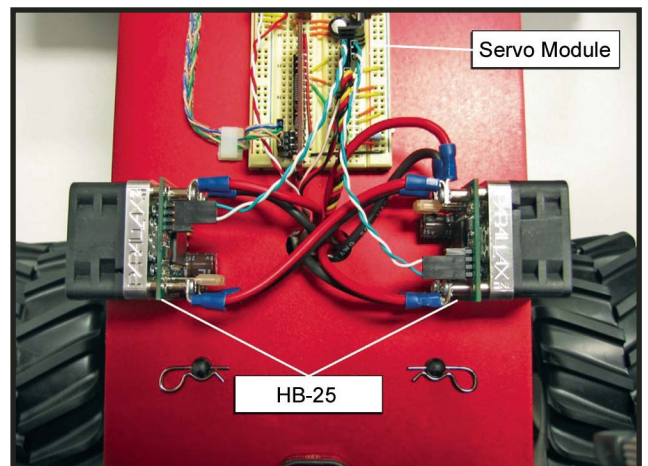
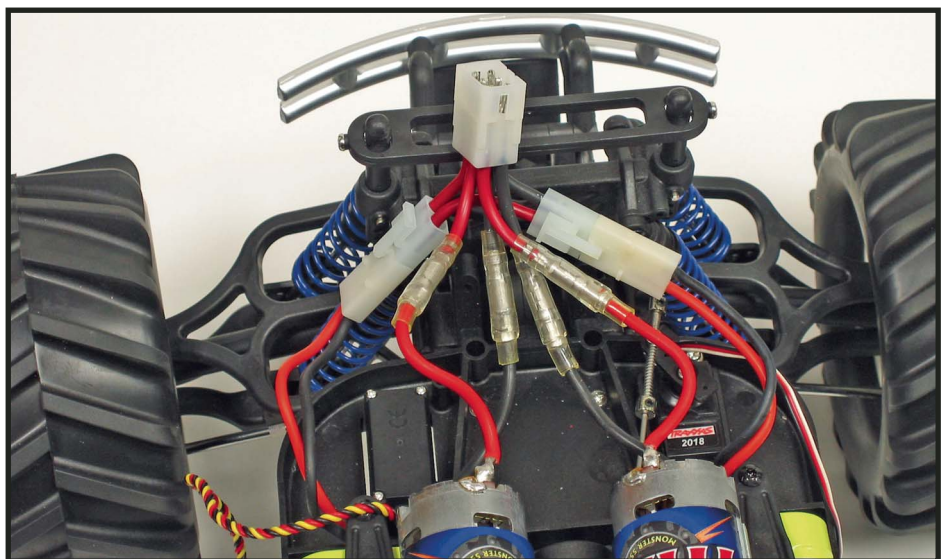


Figure 4. The six-wire connector keeps the wiring well organized.



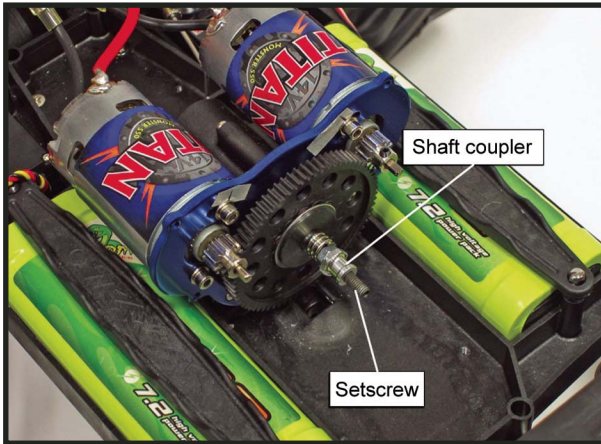


Figure 5. The center transmission shaft extended with coupler and set screw.

the top of the deck increased the amount of wiring between the deck and the chassis. In order to make the wiring more manageable, I used a six-wire 14 gauge connector. It worked so well that I plan on using a similar multi-pin connector for the servo and encoder wiring.

After installing the motor controllers on the deck of the E-Maxx, unscrew and remove the ESC and the radio receiver to reduce weight and free up some space on the chassis. The HB-25 motor controllers greatly expand the speed range of the E-Maxx. It can now crawl along at a snail's pace, race ahead like a rabbit, and hit any speed in between.

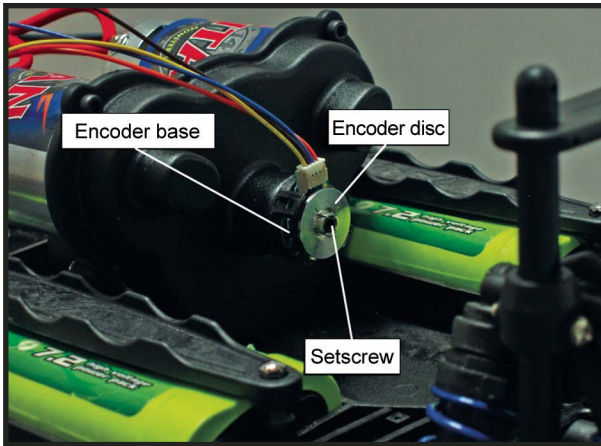


Figure 6. The encoder disc mounted with the lines facing in towards the encoder base.

the capacitor housing on the HB-25s. Trim the spade ends if necessary.

Mounting the motor controllers to

Adding the Rotational Encoder to the Transmission

Now, to monitor the speed, we

simply add an encoder. It would be very useful to know the rotational speed of the E-Maxx transmission. That way, we would be able to vary power to the motors in response to changes in the terrain. To measure transmission rotation, I added a rotational encoder, which translates motion into a stream of electrical pulses.

Knowing the rotational speed of the transmission is not always sufficient, though. For example, if the E-Maxx was on a steep incline, it is possible that it could be moving in a direction opposite of the power applied, especially now that we are able to supply very small amounts of power to the drive motors.

In this situation, I may not be applying enough power to overcome gravity, and our encoder would be reporting movement ... in the wrong direction. To solve this problem, we need a quadrature encoder to know the direction in which the transmission is rotating.

US Digital produces a wide range of optical encoders. I ordered an E4 — a miniature rotary optical encoder with quadrature that fits on the 4 mm drive shaft of the E-Maxx. The configuration I ordered has a shaft hole in the housing that allows the shaft to go through the encoder, so I do not have to be concerned with shaft length. I found that an E4 with transfer adhesive base mounting and a 100-count setscrew hub works perfectly.

To add the rotational encoder:

1. Remove the transmission case and the rubber plug on the case that covers the shaft hole. This will expose the center transmission shaft.
2. Remove the locknut and replace it with a thin 4 mm nut, being careful not to let the clutch plate separate.
3. Tighten the nut all the way and then back it off a quarter turn.

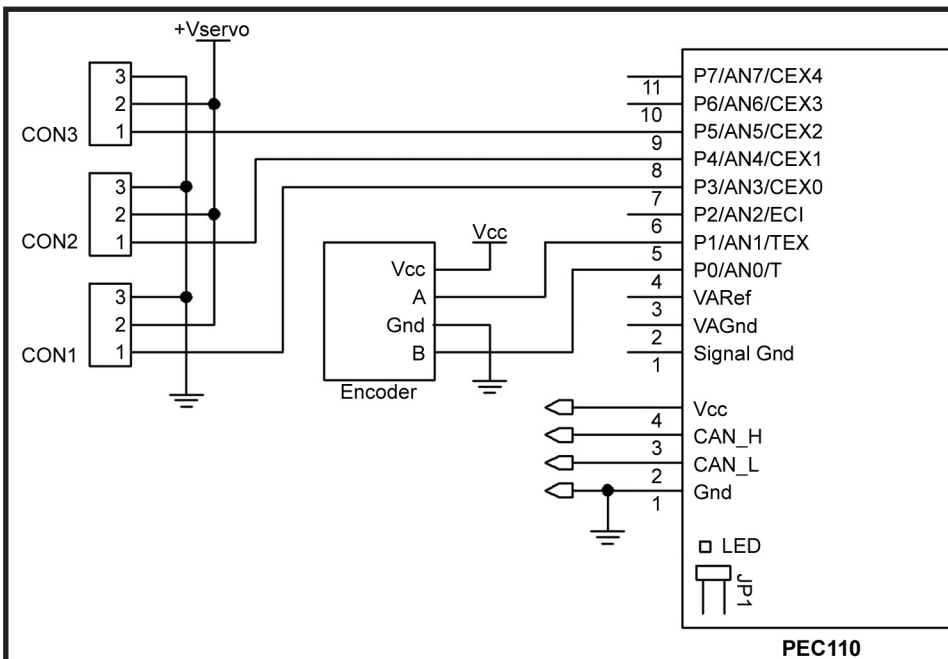


Figure 7. Schematic of the servo and encoder control circuitry.

Figure 8. An illustration of the Servo Module showing how to combine two independent five-volt regulated supplies, three servo ports, and an encoder on one small breadboard.

4. On the end of the center shaft, thread the coupler until it touches the nut, with the wider side facing inward so as not to touch the transmission cover plate. The end of the center shaft should thread half-way through the coupler. If it does not, try adding a washer or two to the shaft between the coupler and the nut to position it correctly.

5. Screw a 4 mm set screw into the coupler to extend the center shaft.

6. Replace the transmission cover.

7. Slip the centering tool over the shaft.

8. Peel the paper backing off of the encoder base and slide it down the centering tool. Make sure to apply pressure evenly until it adheres to the transmission cover plate.

9. Remove the centering tool and slide the encoder disc onto the shaft until it bottoms out against the spacer.

10. Tighten the setscrew.

11. Spin the shaft a few times to make sure the encoder disc is aligned properly.

12. Place the housing cover on the encoder and attach the connector.

The encoder is wired to the servo module, as shown in Figure 7, to process the encoder pulses. The A and B lines from the encoder are connected to the PEC-110's up/down counter and its power is connected to a five-volt supply.

In the last article, power regulation was on the Communications Module. I've

consolidated all of the power regulation circuitry to the Servo Module to avoid having to run multiple unregulated lines. I've also added a switch for the electronics and another for the motor controllers.

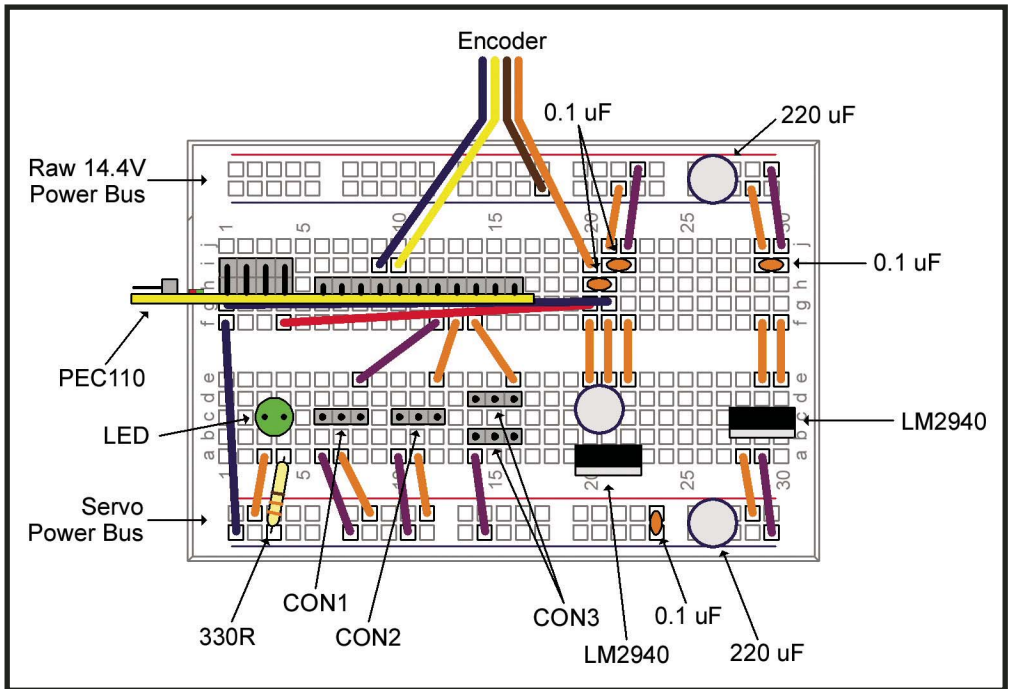
Now, all that's left is the software.

Controlling the Velocity of the E-Maxx

Supplying a constant amount of power to the motors will produce dif-

ferent speeds under different conditions. For example, it takes more power to move up an incline or through sand than it does to move across a hard, level surface. To maintain a constant velocity, the information from the encoder can be used to adjust power to the motors in response to changes in terrain.

The eight-pin port extender (PEC-110 by Machine Bus) I chose in the March article has a closed-loop control mode that will make the necessary



LISTING 1

```
// Create a new closed loop motor reference
EncodedMotor encodedmotor_createEncodedMotor(CommBus C, uint8_t id);

// Run the motor at the specified rate until commanded otherwise.
void encodedmotor_setRate(EncodedMotor E, int16_t rate );

// Run motor at the specified rate until its incremented/decremented count times.
void encodedmotor_setRelativePosition(EncodedMotor E, int16_t rate, int32_t count );

// Run the motor at the specified maximum rate until the encoder reached count.
void encodedmotor_setAbsolutePosition(EncodedMotor E, int16_t rate, int32_t count );

// Clear the count
void encodedmotor_resetCount(EncodedMotor E);

// Get the current count
void encodedmotor_getCount(EncodedMotor E);

// Get the current rate
int16_t encodedmotor_getRate(EncodedMotor E);

// Dispose of the encoded motor
void encodedmotor_disposeEncodedMotor(EncodedMotor E);
```


PARTS LIST

Item/Description

- ⇒ (2) Parallax HB-25 motor controllers
- ⇒ 14 gauge silicone insulated wire
- ⇒ 14 gauge bullet connectors
- ⇒ NiCad battery connectors (two pairs)
- ⇒ Six pin connector
- ⇒ 14 gauge spade connectors
- ⇒ 22 gauge spade connectors
- ⇒ E4-100-157-HT miniature optical kit encoder and cable
- ⇒ Molex .1" female housing, pins, and male header
- ⇒ 4 mm coupler
- ⇒ 4 mm hex head setscrew
- ⇒ 4 mm nut

Supplier

- Parallax, Inc. (www.parallax.com)
 Al's Hobby Shop (www.alshobbyshop.com)
 Al's Hobby Shop (www.alshobbyshop.com)
 Al's Hobby Shop (www.alshobbyshop.com)
 Jameco (www.jameco.com) Part No. 142228CE
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 Any hardware store
 US Digital (www.usdigital.com)
 Jameco (www.jameco.com)
 Tower Hobbies (www.towerhobbies.com has it listed as 'Trinity Shock Spacer Nitro Spyder')
 Any hardware store
 Any hardware store

firmware on the PEC-110 measures the difference between the desired rate set point and the actual shaft rate. The velocity control algorithm on the PEC-110 uses that error to adjust the power to the motors.

With the encoder attached, the application software on the PC — to interface to an encoded motor — changes from "Servo" to "EncodedMotor," as shown in Listing 1.

I have written a few applications to take advantage of velocity control. One

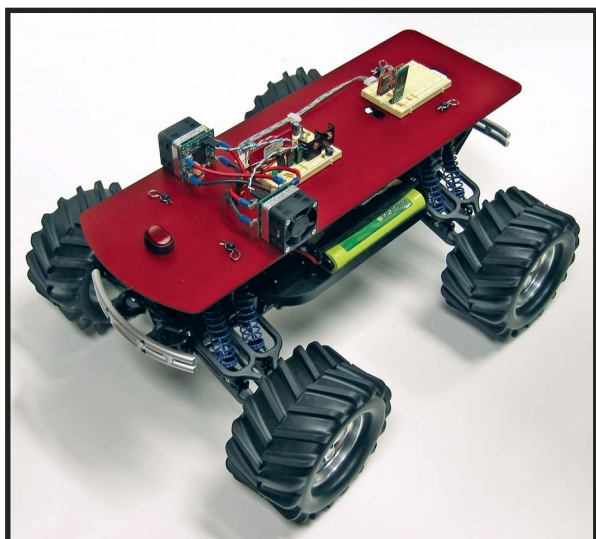
application maintains a constant velocity while driving across grass or pavement, as well as while traveling up and down inclines. Another application drives the E-Maxx 20 feet straight towards a wall and stops just short of it. I can then use the joystick application from the March article to drive the E-Maxx back to me without leaving my chair.

Next Up: Navigation

The modifications to control the speed of the E-Maxx are complete. The HB-25s provide fine-grained control over the motors, and the encoder helps determine how fast the E-Maxx is moving in forward or reverse. As a direct result of our modifications, the E-Maxx can:

- Maintain constant speed under all conditions.
- Move at very low speeds.
- Record the distance traveled.
- Move a specified distance and velocity.

In the next article, we will tackle dead reckoning. The information returned from the encoder will be used in odometry calculations. We will also add a digital compass to the E-Maxx so it knows exactly which direction it is heading. To test the hardware modifications and the software, we will have the E-Maxx traverse a set of waypoints using the digital compass and odometry. **SV**



power adjustments in response to the encoder data. By adding an encoder to the PEC-110, I can now drive by velocity.

In other words, instead of specifying a power level using servo position commands, I can send the Servo Module the desired rate for the motor shaft to rotate in counts per second. The

Figure 9. The E-Maxx with motor controllers and encoder, ready to go.

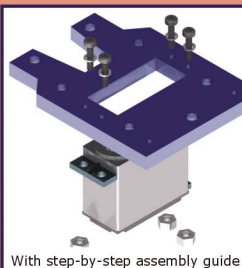
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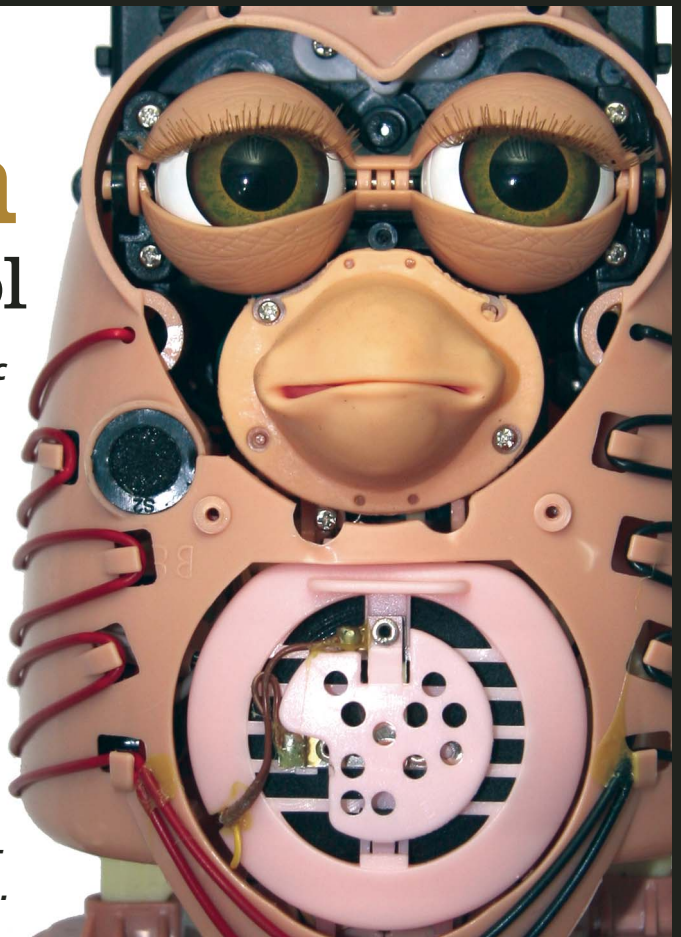
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VOICE Recognition for Robotic Control

Voice recognition is the anthropomorphic feature most commonly associated with autonomous, intelligent robots. The impression of intelligence fostered by a robot's ability to respond appropriately to spoken commands is central to creating an emotional bond with a human operator. Witness the popularity of voice recognition in well-known animatronic and robotic toys, such as the Furby and Robosapien series. The Furby (shown without fur in the photo to the right) uses voice recognition, appropriately animated facial expressions, and voice synthesis to create an emotional bond with children.



A skinned Furby™ showing the microphone next to the beak and the speaker in the abdominal area.

by Bryan Bergeron

The use of voice recognition as the primary user interface to a robot has value beyond providing a semblance of intelligence. Examples of voice recognition applied to practical problems range from the hands-free guidance of motorized wheelchairs and similar devices by the disabled and surgical assistant robots for surgeons, to robotic tank turret controllers that enable drivers to aim while steering the vehicle. For the consumer, a voice recognition interface lowers the age threshold for programming and interacting with a robot.

To the serious and amateur robotics enthusiast, voice recognition can be thought of as a class of intelligent sensor, akin to IR and ultrasound rangefinder modules. In this regard, voice recognition is a means of endowing robots with increased autonomy by increasing their ability to sense and interact with their environment. This

article provides an introduction to voice recognition, including a practical example of how an off-the-shelf voice recognition board can be used to control a robot arm.

Voice Recognition Basics

Voice recognition involves the analysis of large amounts of analog data in near real time. In the age of analog computers, this didn't present an inordinate obstacle. Voice recognition was successfully demonstrated in analog computers over a half-century ago [1]. However, development of voice recognition as a user interface was stymied by the move from analog to digital computers. Furthermore, because of the cost and scarcity of early computer hardware, voice recognition remained a laboratory curiosity for decades.

With the advent of microcomputer-controlled DSP chips that provided A-to-D conversion and high-speed data manipulation, commercial voice recognition systems appeared in specialized markets in the 1980s. The PC-based voice recognition industry took off when DSP-based sound processors became incorporated into standard PC design in the form of now ubiquitous sound cards.

Through a series of mergers and acquisitions, the speech recognition companies Kurzweil AI, Dragon Systems, and Lernout & Hauspie became ScanSoft and, more recently,

REFERENCE

- [1] Automatic recognition of phonetic patterns in speech, by H. Dudley and S. Balashek. *Journal of the Acoustic Society of America*. 1958: pp. 721-39.

The impression of intelligence fostered by a robot's ability to respond appropriately to spoken commands is central to creating an emotional bond with a human operator."

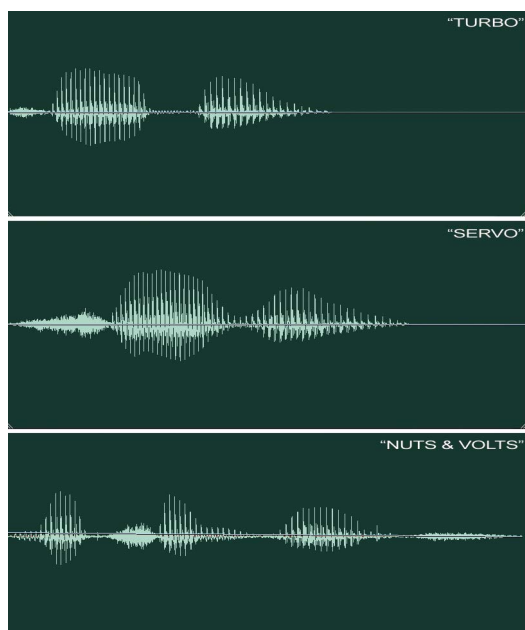


Figure 1. Audio amplitude envelopes for the words "Turbo," "Servo," and "Nuts & Volts."

Nuance. IBM and Philips also remain as key players in the field of PC-based voice recognition. Unfortunately, the technology hasn't evolved in years, and general consumer demand for PC-based voice recognition products is lackluster.

In contrast, demand for voice recognition in small footprint devices, from cell phones with voice dialers and PDAs, to robotic toys, has propelled developments in embedded voice recognition solutions. Today, for the price of a standard microcontroller, it's possible to buy a 40-pin DIP that uses an internal microcontroller and RAM to provide stand-alone voice recognition and voice synthesis.

Definitions

The terms "voice recognition" and "speech recognition" are often used interchangeably, even though there are significant differences in the two technologies. Both technologies involve the application of pattern recognition techniques to categorize audio signals, but the algorithms used in speech recognition are more complex. Neither technology results in true speech understanding.

Voice recognition — perhaps more appropriately named sound recognition — uses pattern matching based on simple sound metrics, such as amplitude, duration, and spectral matching. Most of the robotic toys with embedded voice recognition, such as the Furby, use voice recognition.

To understand how sound metrics can be used as the basis of pattern matching in voice recognition, consider the amplitude envelopes for the words "Turbo," "Servo," and "Nuts & Volts" shown in Figure 1. Visually, the tracings for "Turbo" and "Servo"

are more similar to each other than to the tracing for "Nuts & Volts." A voice recognition system designed to work with this three-word vocabulary would be expected to have little difficulty distinguishing "Turbo" from "Nuts & Volts," based on the amplitude envelopes alone.

To increase *recognition accuracy*, a second metric can be used, such as the spectral analysis of each spoken word or phrase (see Figure 2). The spectral analysis of "Servo" reveals pronounced high frequency content at the start of the signal. This sibilance is absent in the spectral analysis of "Turbo." As in the amplitude envelopes, the spectral analysis of the phrase "Nuts & Volts" is significantly different from the spectral analysis of the other two sounds. Armed with spectral and amplitude metrics, the three signals can be easily differentiated and identified. In a voice recognition system, the signal comparisons are performed mathematically by specialized hardware and software.

Speech recognition technology combines the basic sound metric analysis used in voice recognition with domain- and context-specific language models. A language model is simply a list of word sequences associated with probabilities.

A language model based on three-word groups or trigrams contains a list of three word sequences and probabilities. Consider the phrase "Jack hit the red ball." Based on audio metrics alone, the top contenders for the last word in the phrase might be "fall," "ball," "wall," and "gall," in the following order:

Word	Rank
Fall	1
Ball	2
Wall	3
Gall	4

Now, examining the trigrams beginning with "the red _____," the

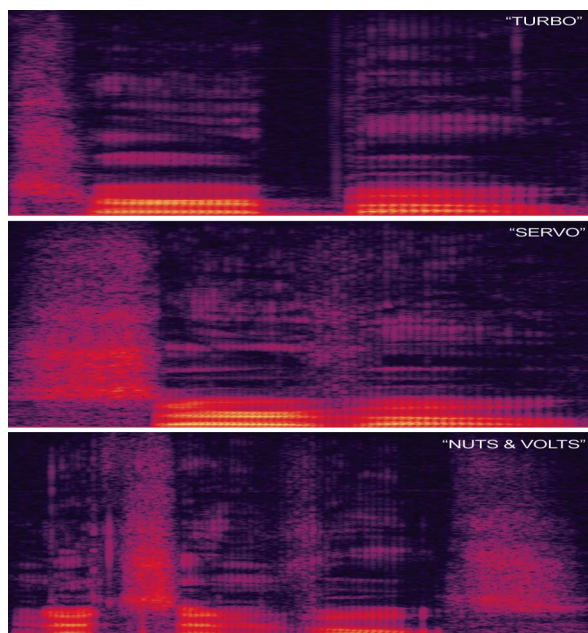


Figure 2. Spectral displays for the words "Turbo," "Servo," and "Nuts and Volts." Time is along the x-axis and frequency is along the y axis.

probabilities associated with each of the top contenders might be:

Trigram	Probability
"the red fall"	0.1
"the red ball"	0.6
"the red wall"	0.6
"the red gall"	0.2

In this language model, the trigrams "the red ball" and "the red wall" are more likely than "the red fall," or "the red gall." With this information, "fall" is demoted in the top contender list, and "ball" is ranked as the most likely recognized word.

Language models based on word pairs or bigrams require less memory for the probability lists, but provide less helpful information. Conversely, using more than three word phrases consumes exponentially more computer resources than trigram models. PC-based speech recognition systems that use trigram language models, when used with a quality microphone, can achieve a recognition accuracy of nearly 98%.

The typical PC-based speech recognition system requires serious hardware. A dictation system capable of recognizing hundreds of thousands of words (*large vocabulary*) of continuous, normal speech (*continuous recognition*) requires several hundred MB of disk space. Furthermore, PC-based speech recognition systems are relatively *speaker dependent*, in that the user must train the system by providing examples of pronunciation (*enrollment*). The subsequent processing and model building, which is key to achieving maximum recognition accuracy, require considerable computational power.

Options for Robotics

With the appropriate hardware interfaces, PC-based speech recognition systems can be used for robotics control. However, most robot developers opt for inexpensive voice recognition solutions that support semi-autonomous, smaller footprint operation. Most embedded voice recognition solutions support a small vocabulary of a few dozen discretely spoken words or phrases. A

degree of speaker independence is possible by capturing metrics for the same word or phrase spoken by different people.

Despite the limitations of voice recognition, the technology has an advantage over more capable speech recognition in certain robotics applications. For example, because there is no language model, a mobile robot equipped with voice recognition can be programmed to respond one way to the bark of the family dog, and differently to the meow of the cat. Similarly, a delivery robot in a hospital or office building can be programmed to automatically park at the sound of a fire alarm.

One of the obvious options for experimenting with voice recognition as a form of robotic control is to hack voice-enabled robotic and animatronic toys, such as the Furby or Robosapien. Owners of the Robosapien can explore the Robosapien Dance Machine, which is free, open source software for the Robosapiens. The software incorporates the DARPA funded CMU Sphinx speech engine, which provides speaker-independent, large vocabulary, continuous speech recognition.

The inexpensive Furby toy has a fixed, 10-phrase vocabulary. Furthermore, like many embedded voice recognition systems, Furby is constantly listening for voice commands. To prevent a flood of false positives, Furby must be activated with the phrase "Furby" before it will respond to one of the 10 fixed phrases, such as

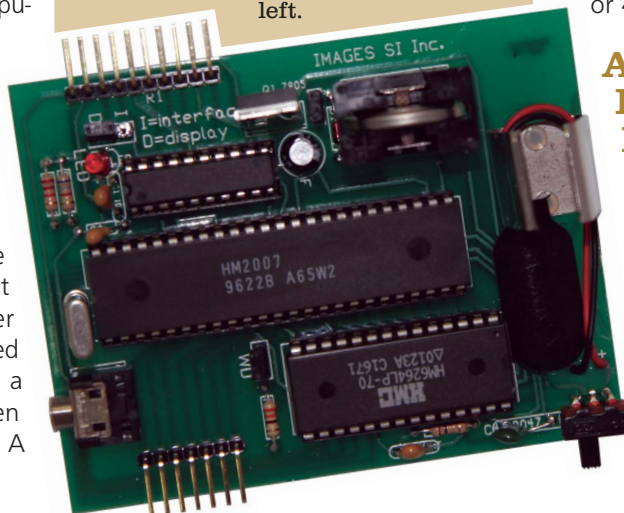
"Tell me story."

A more direct approach to adding a speech recognition interface to a robot is to use a chip designed expressly for voice recognition experimentation and development. Two notable examples are the MH2007 and the more recent and capable VR Stamp. For deep-pocketed experimenters, the VR Stamp offers impressive speech recognition and synthesis capabilities in a single chip. Individual VR Stamps are only \$30. However the development kit — which is required to program the chip — is about \$500.

The HM2007, available with a kit or an assembled board from The Images Company, is a more affordable, albeit less powerful, option. The \$80 weekend kit — the SR-06 — includes an HM2007, 8K of SRAM, three circuit boards, and a handful of supporting components. The two small boards are used for programming and testing and can be removed during operation. The main board (shown in Figure 3) provides a slot for a CR023 for the volatile RAM and a nine-volt battery clip for primary power. There is no power jack or mounting holes.

The SR-06 kit and SR-07 assembled board provide experimenters with a gentle introduction to voice recognition without having to learn a development environment. Although the HM2007 is capable of recognizing 40 one-second sounds or 20 two-second sounds, there are only 10 distinct outputs available on the optional interface kit, the SRI-03. While 10 channels may be sufficient for simple projects, a less expensive and more capable solution is to use a BASIC Stamp or other micro-controller and work with the full 20 or 40 word vocabulary.

Figure 3. Layout of the SR-07 Speech Recognition Kit. The HM2007 is visible in the center of the board, and the 10-pin output connector is in the upper left.



Adding Voice Recognition to a Robotic Arm

Controlling my CrustCrawler SG6-UT in real-time has always been problematic. Although there are several applications that support the creation of scripts that can be executed in a batch mode, these tools aren't suitable for tasks like an interactive game of chess. A popu-

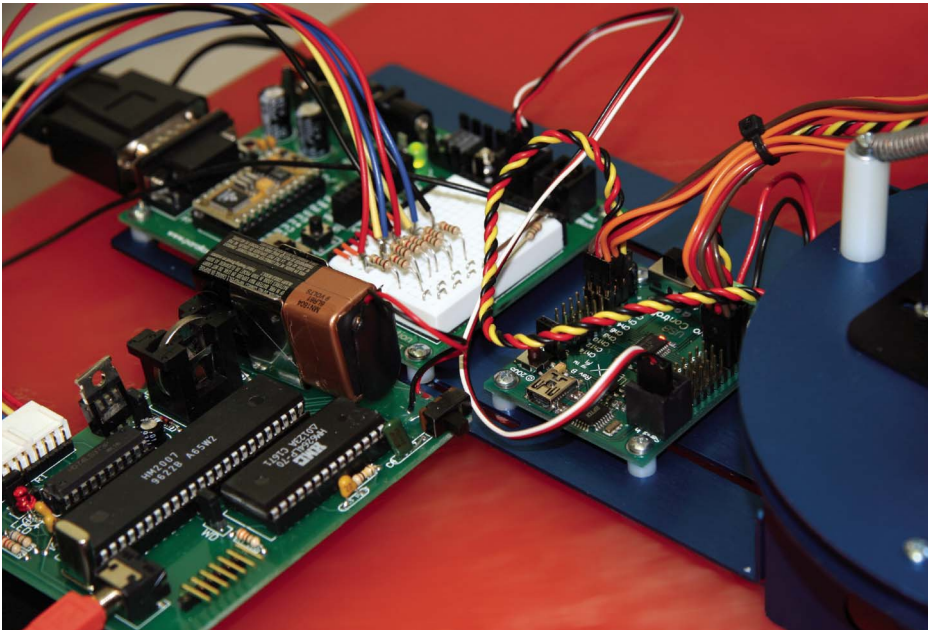


Figure 4. Connecting the SR-07 and the Board of Education on the robot arm.

lar option for real-time control is to use a six-channel RC unit, but learning and remembering which axis controls which servo is a constant challenge, especially when the RC unit is used on multiple robots. A more educational option is to use a MH2007-based SR-07 to control the arm. The system described here provides voice control over each of the arm's six joints, together with an example of a macro to park the arm in a position that doesn't overly stress the springs or servos.

Hardware

The standard configuration of the SG6-UT, a six-degree-of-freedom robot arm made of aluminum, includes a Parallax Board of Education (BOE) and a 16-channel Parallax Servo Controller. Maximum load capacity is about 14 ounces, with reduced capacity as distance from the base of the arm increases. Adding voice control to the SG6-UT is a simple matter because the unit is a series of six independent servos connected to off-the-shelf Parallax electronics. As such, the integration of voice recognition to the SG6-UT should be

generalizeable to any project utilizing the same electronics.

Connecting the SR-07 to the BOE involves extending the 10-pin connector on the top of the SR-07 to the first eight input pins of the BASIC Stamp (see Figure 4). The first pin on the SR-07, ground, is connected to VSS on the BOE to establish a common ground. The second pin on the SR-07, +5 V, isn't used. Pins 2-10 of the SR-07 are connected to the first eight input pins of the BASIC Stamp. Use 2.2K ohm resistors between the input pins

“Eventually, voice recognition and speech recognition will become commodity items for robotics work ... the current generation of voice and speech recognition products represents an experimental platform upon which innovative experimenters can work toward the elusive dream.”

and VSS pin of the Stamp to minimize noise.

The vocabulary length jumper on the SR-07 is configured for 20 words. Although it's possible to use the 40-word setting, accuracy will suffer. As a note of caution, because the SR-07 lacks mounting holes, it's a good idea to attach self-adhesive rubber feet to the back of the board to avoid shorting

the board on a conductive surface.

Software

The design of the software follows the state diagram shown in Figure 5. Starting with the left-most node, the eight-bit output of the SR-07 is read by the BASIC Stamp. If the microcontroller encounters one of the error codes — 55 (words too long), 66 (words too short), or 77 (no such word in vocabulary) — then it returns to read the SR-07 output. The meaning of the error codes is irrelevant. The point is to ignore invalid codes.

When the SR-07 recognizes a word and produces a valid code, the code is compared with the previously received valid code (second node). If the code is the same as the previously encountered code, then the program returns to the input stream. If the code is new (third node), then the appropriate servo is updated (fourth node), and the program returns to read the SR-07 output.

Referring to the code listing, 14 spoken commands are assigned codes 1-14. The words or phrases can be literal, such as "Base Clockwise," a non-English phrase, or a unique sound less than two seconds in duration. Constants are defined to identify and provide the safe operating ranges of each of the six servos. In this example, the base can move between 20 and 160 degrees. The use of degrees instead of servo controller units allows byte variables and constants to be used instead of memory-hungry words. The cost for this memory savings is a small amount of computational overhead in converting from

degrees to servo controller units.

Beginning with the Main program, data from the SR-07 are loaded into *SRINPUT*, which is then examined for an error. Although the 20-sound vocabulary is used in this example, the error checking assumes a maximum of 40 sounds. Any codes over 40, including the 55, 66, and 77 codes, are detected by checking the highnib of *SRINPUT* for

a number greater than four. *ChangeByte* is used as a temporary storage bin to compare incoming codes with the last valid code received from the SR-07.

Consider the program operation when SRINPUT takes on a new value of \$1, corresponding to the "Base Clockwise" command. First, all servos are stopped with the *StopAll* subroutine, which calls *StopServo* for each of the six servos. The *StopServo* routine queries the controller for the current position of a servo and sets the target of the servo to the current position. The effect is to stop the servo immediately. Note that only one servo is active at a time.

Next, the *Move_Joints* subroutine is called. Because *SRINPUT* = \$1, the first *IF-THEN* statement is activated. As a result, the controller channel *pscChannel* is set to 1, and the target for the base servo is set to 160 degrees. The 160 degree value is converted to controller units, and the result is written to the base servo.

Operation

With the hardware connected and software loaded in the BS2p, the first step is to train the SR-07. Simply key in a code on the SR-07 keypad, depress the "Train" key, and speak the phrase corresponding to the code. Recognition accuracy can be tested immediately by repeating the phrase, and a phrase can be re-recorded at any time. It's also a good idea to leave the keypad attached during initial operation of the arm. Control codes can be keyed in directly in an emergency.

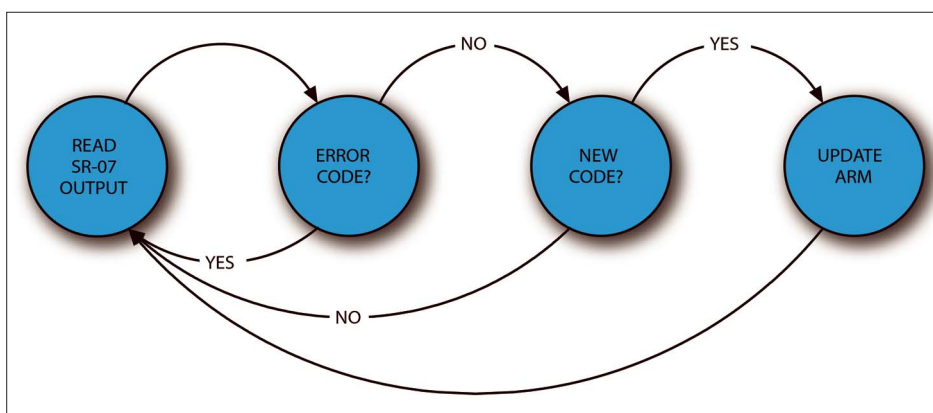


Figure 5. Program flow.

Furthermore, the keypad can be used to input control codes for debugging purposes.

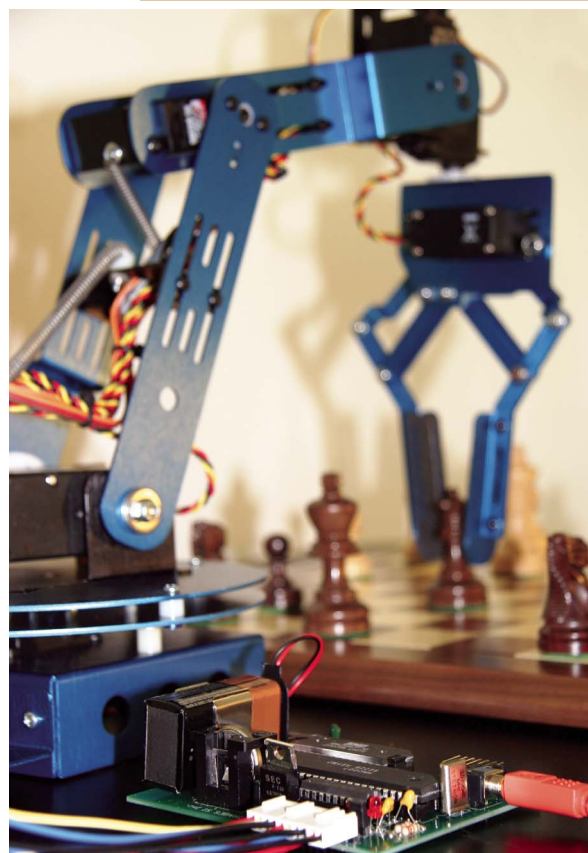
Because the SR-07 has a recognition lag time of a few hundred milliseconds, operating the arm under voice control requires a little practice. Anticipate the final position of the arm and issue the "Stop" command before a joint is in the desired position. Work with slow ramp rates at first, and then move up to faster ramp rates once you're accustomed to the operation of the voice controller. With a moderate ramp rate, it's possible to use the arm under voice control for intricate tasks, such as moving chess pieces on a board in real time (see Figure 6).

including multi-core, parallel processing designs, will enable developers to access PC-class processing power on small footprint devices. However, the elusive goal of speech understanding won't be addressed by faster hardware. New software algorithms and approaches to speech understanding must be developed. Toward this end, the current generation of voice and speech recognition products represents an experimental platform upon which innovative experimenters can work toward the elusive dream. **SV**

Figure 6. The SR-07 and SG6-UT robot arm in action.

Future Directions

Eventually, voice recognition and speech recognition will become commodity items for robotics work. New micro-controller architectures,



RESOURCES

CrustCrawler

www.crustcrawler.com

Source of the SG6-UT Robotic Arm.

Parallax

www.parallax.com

Source of the BASIC Stamp and Parallax Servo Controller.

Robosapien Dance Machine

www.robodance.com

Open-source software for hacking the voice

recognition within the Robosapien robot line.

Images Company

www.imagesco.com

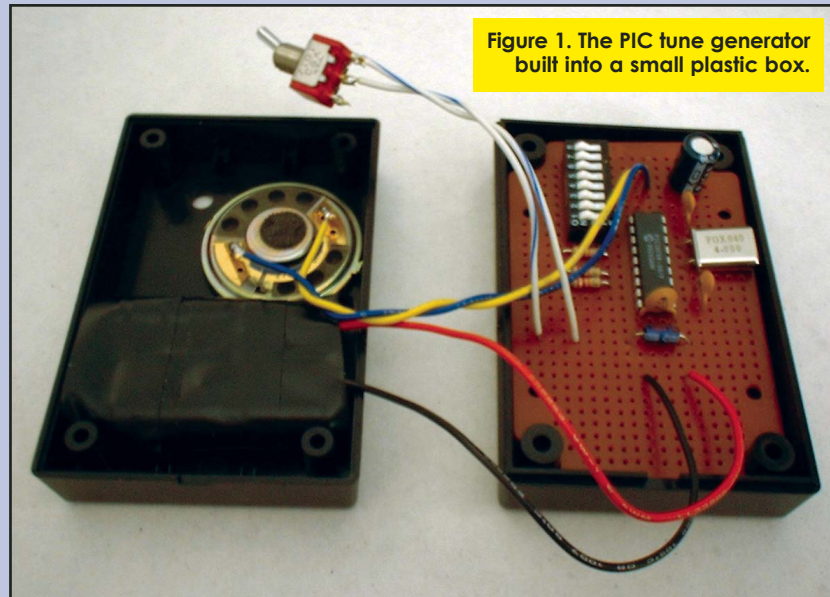
Distributor of the SR-07 Speech Recognition and SRI-03 Interface Kits.

Sensory, Inc.

www.sensory.com

Source of the VR Stamp voice recognition and synthesis module and development kit.

ADD SOMETHING 'NOTE' WORTHY TO YOUR NEXT BOT



With This PIC Tune Generator

by Michael Helm and Jonathan Wheeler

Here is a very simple PIC-based tune generator that will play simple melodies for use as a stand-alone toy or as an add-in to other projects. The circuit is so simple and low-cost that it could be included in almost any gadget you are building just to add a little jazz to your project.

Think about having your robot play a fanfare as it charges forward. You could also structure one of these into an electronic music box. A couple of sample tunes are provided in the accompanying source code, but you can program any tune of your choice by changing the note sequence in the code. The total cost of this tune generator is only about \$10 including a case to house it in. The project is designed around a \$5 PIC16F84 micro-controller, and only needs a small handful of other low-cost components to complete the circuit.

Theory of Operation

The circuit for the tone generator is shown in Figure 2. A note is generated by toggling output port bit RA0 (pin 17) on the PIC at an audio rate. A tune is formed by generating a series of notes and pauses. The software includes subroutines to generate various notes. A range of a couple of octaves is available in the code provided with this project, but that could be extended by adding a few more note generator functions. The different note lengths, such as eighth, quarter, half, etc., are formed by calling a particular note subroutine — once for an eighth note, twice for a quarter note, etc.

This is a simple system, so only one note is played at a time to generate simple melodies. The square wave output from the zero pin on PORT A of the PIC is fed through a capacitor to isolate the DC levels from the speaker. Since we want precise frequencies for the notes, a 4 MHz crystal is used to control the master clock frequency on the PIC16F84.

The tune to be played is selected by S1 and the tempo is selected between slow and fast by S2. S3 controls the power. Cycling the power will cause the PIC to reset to the beginning of the tune. The MCLR reset input (pin 4) is held high with pull-up resistor R1 so the PIC will run.

The software reads the state of S1 to determine which tune to play and the state of S2 to determine the tempo of the tune. S1 is read once or twice during each measure of the current song playing, so a tune will finish the current measure or half measure before changing tunes. The tempo switch S2 is checked once for each note played, so tempo can be changed almost instantly.

S1 and S2 are connected to the first two pins RB0 and RB1 (pins 6 and 7) of PORT B, which is configured as an input port. Both of these inputs are pulled to a high logic state with 22K pull-up resistors R2 and R3. When S1 or S2 are closed, they will set the respective input to a logic low state to select the particular mode of operation.

Construction

There are several ways to build this project. A version built into a small plastic box is shown in Figure 1. The circuit is small enough and simple enough to be built into almost anything. The size is mostly limited by how small of a speaker you can find. The electrical layout is not particularly critical, although the crystal X1 and its associated capacitors C3 and C4 should be wired close to the PIC16F84. Also,

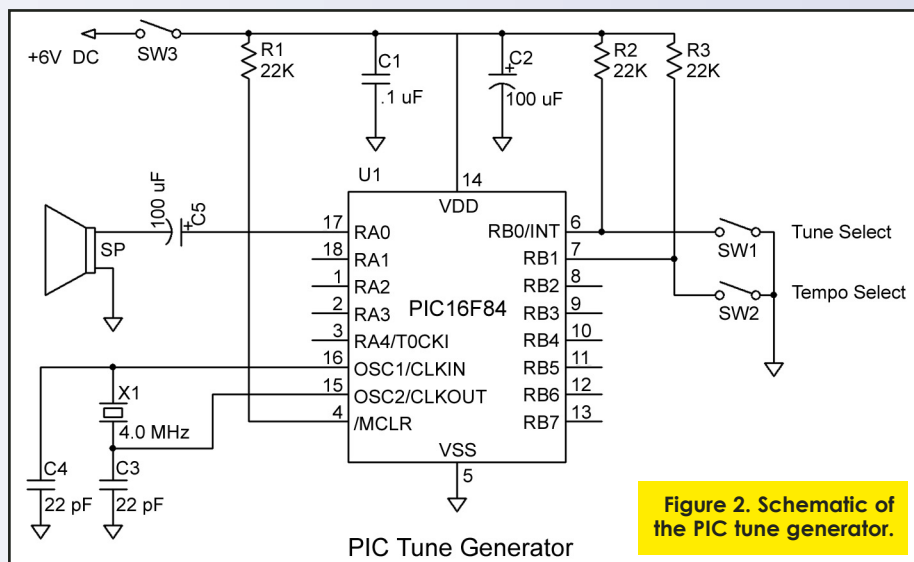


Figure 2. Schematic of the PIC tune generator.

C1 should be wired close to U1.

The remaining wiring is not critical. The speaker and C5 are not very critical either. Use what you have on hand. Anything from a four-ohm to 32-ohm speaker will work okay, and just about any electrolytic capacitor between 1 μ F and 220 μ F will work for C5. The circuit will operate from 4.5 to six volts DC. If you need to use a power source with more than six volts, be sure to include a five- or six-volt voltage regulator since the PIC chip has an upper voltage limit of six volts DC.

Checkout

As soon as power is applied, the circuit will start playing whichever tune is selected by S1 at the tempo selected by S2. You can change tempo at any time since tempo is checked each time a note is played. Tune selection is checked every few notes. The circuit will continue to play the selected tune in a repeating mode until the power is turned off by S3.

Modifying the Software for Custom Tunes

The source code listing is available on the *SERVO* website (www.servomagazine.com). It is well commented and should be reasonably easy to follow. To customize your own tune, just change the sections for Song 1 and Song 2 to use your own sequence of notes and timing by calling the desired note gener-

ator functions in the sequence needed for your tune. Make sure you don't change the actual note generator functions since the timing in those is critical to provide accurate musical notes.

The software is set up to provide two short tunes, which is about the limit for the memory size of the PIC16F84 chip, but this could be expanded if you used a different PIC chip with more memory. If a really long tune is desired, it might be necessary to only play a single tune in order to have enough memory space.

If some measures in a song are repeated, those can be coded as sub-routines that are called when needed, thus saving some memory space. This is done with the second song in the code provided, where Measures 1 and 3 are the same and where Measures 2 and 4 are the same. The two tunes included in the software provided are "Yankee Doodle" and "London Bridge." The code is easily modified for your own custom tune as described above and in the actual code listing. **SV**

Michael Helm is an Instructor at the College of Engineering at Texas Tech University in Lubbock, TX. He teaches embedded systems design and digital circuit design.

Jonathan Wheeler is a senior majoring in Computer Science at Texas Tech University.

Parts List

- | | |
|--------------|--|
| • C1 | 0.1 μ F 50V ceramic disc capacitor |
| • C2, C5 | 100 μ F 50V electrolytic capacitor |
| • C3, C4 | 22 pF 50V ceramic disc capacitor |
| • R1, R2, R3 | 22K 1/4 watt resistors |
| • S1, S2, S3 | SPST switch |
| • SP | Small speaker, four to 32 ohm |
| • U1 | Microchip PIC16F84 microcontroller |

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Among the more fascinating developments in electronics, the integrated circuit rates high on my list. They are the engineer's Lego® blocks. All kinds of functions in both analog and logic format are available, taking a lot of drudgery and guesswork out of the design process. The circuit I am about to show you will demonstrate this idea. Just imagine if you would have to do this entirely with transistors or worse, with radio tubes. (Yes, Virginia, we used to do that.)

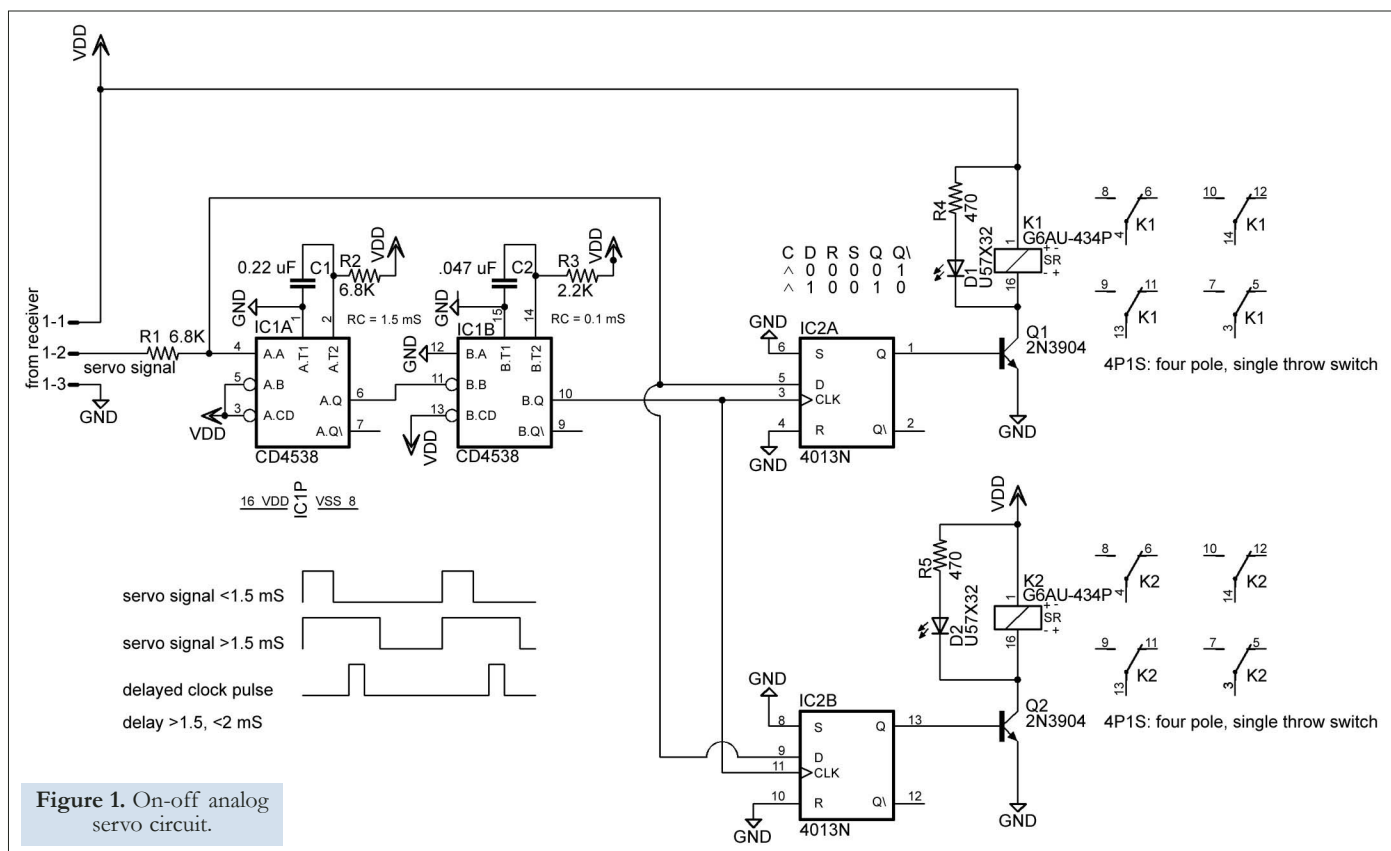


Family picture of the Fircelli actuators.

The Servo Alternative

by Paul Weijers

THE OBJECTIVE: *I started out by looking for a circuit that would allow me to switch a light on a radio-controlled model on and off. The only examples I could find were not to my liking. The first one used a servo and a microswitch. The arm on the servo turns the switch on and off. Simple and effective, but it will cost you a servo. The second solution I found also used a servo but with the motor removed and replaced with a relay stuck on the side of the servo body. A bit more effort, although I am sure it works.*



The Design Process

Let's go back and look at the input to a servo. This is a repetitive pulse with a minimum width of one millisecond and a maximum width of two milliseconds. In a typical six- or eight-channel RC system, there are one or two channels available for auxiliary purposes. While airplane controls such as throttle, ailerons, etc., are operated with potentiometers, the auxiliary channels are switch operated. They generally have an output pulse at the receiver of either one millisecond or two milliseconds without any in between values. The challenge then is to switch ON when the pulse is two milliseconds and to switch OFF when the pulse is one millisecond, or vice versa. We want to achieve this with a minimum of components.

Take a look at the schematic in Figure 1. A standard servo cable connects to the input of IC1 (pin 4), which is a re-triggerable multivibrator, CD4538. The first half of IC1 is triggered by the leading edge of the

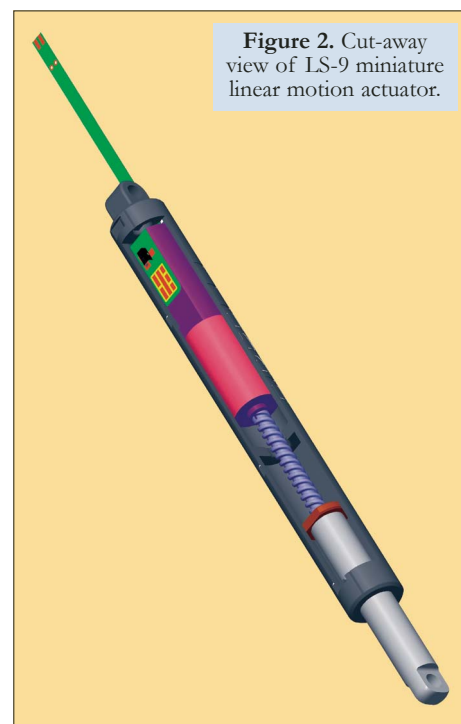
incoming pulse and produces a positive output pulse of about 1.5 milliseconds. This value is determined by R2C1. The trailing edge of this pulse, in turn, triggers the second half of IC2 (pin 11) which has a positive output pulse of about 100 microseconds. This pulse width is set by R3C2. The pulse occurs either when the incoming signal is equal to one millisecond (i.e., when the signal is low) or when the incoming signal is high.

The next stage is a flip-flop, CD4013. Grounding the Set and Reset inputs allows this device to act as a simple data transfer switch. The 100 microsecond pulse acts as the clock pulse for this stage. The clock pulse causes the data input to transfer to the output. The data for this stage is the incoming signal which is either low or high when the clock pulse triggers the flip-flop. So, at this point we have a basic switching arrangement.

The Output Circuits

The output circuits are simple.

Transistor Q1 — 2N3904 — is turned on when the Q output of IC2A goes high and turns off when this output goes low. The transistor operates relay K1.



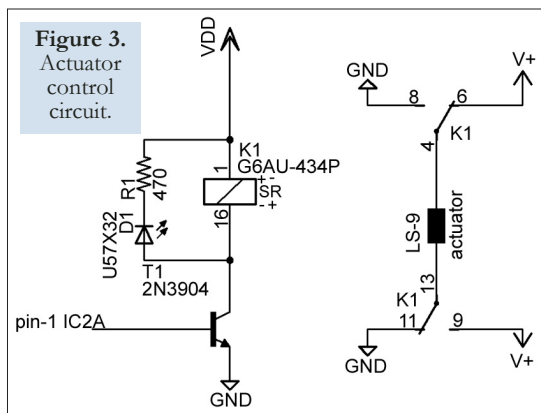


Figure 3.
Actuator
control
circuit.

For the relay shown, you now have four double pole, single throw switches. IC2B operates relay K2 at the same time for a total of 8DPST switches. The small LEDs — D1 and D2 — are convenient indicators of the state of the circuit.

Power for the integrated circuits and the relay circuits is supplied by the receiver's battery. To ease the load on the receiver's battery, you can use a separate battery for the relay circuits. Just make sure that the ground between the two batteries is common. Also, whatever devices are operated via the relay's contacts should be powered from a separate battery. Remember, lights can demand quite a bit of power.

While this is a rather extreme circuit as far as the number of switches is concerned, it can, of course, be reduced by not connecting IC2B and leaving out K2. Further reduction in size — if you only need a single ON/OFF switch — can be achieved by using a relay with a single pole. You can also take advantage of the fact that IC1 and IC2 are available with a small footprint instead of the standard DIP form.

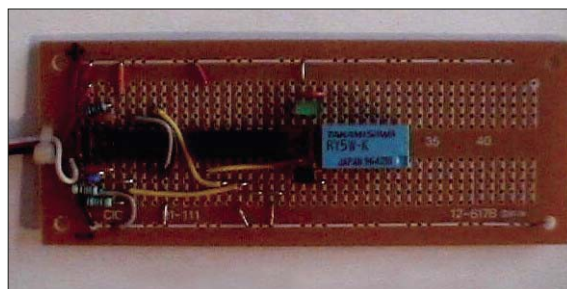


Figure 4. The
engineering model.

What Else Can You Do?

Anything in an RC plane or robotic structure that requires a simple ON/OFF circuit can be operated in this manner. For example, in model airplanes one often uses a glow driver to keep the engine ticking over at low RPMs. This circuit needs to come on only when the throttle is below about 25% of the maximum setting. Use a Y connector to the throttle channel and adjust the RC value of R2C1 accordingly.

Serendipity

The dictionary describes serendipity as *a gift of finding valuable things in unexpected places by sheer luck*. In the process of designing this circuit, I came across a news item in *Nuts & Volts* about a new type of miniature linear motion actuators from Fircelli Technologies, Inc. Usually, one thinks of actuators or solenoids as rather clumsy items. They are energized by applying a voltage in one direction and then returned to their original position by spring action. The Fircelli actuators are quite different.

They are small, powerful, motor-driven, and can be electrically operat-

ed in both directions. The actuator draws no current while at rest — a considerable energy savings in battery-operated equipment. At the time of writing, they are not yet widely available, but full production was expected to start in March 2006.

Fircelli Industries was kind enough to lend me a pre-production model of the LS-9 model (see Figure 2). It lived up to expectations and led me to think that there are a variety of places where they would be far more useful than a regular servo. Particularly interesting was the fact that it takes a few seconds to travel the full range rather than the slam bang normally associated with actuators. Off-hand, I can think of several places — especially in large model airplanes or RPVs — where such an actuator could be applied:

- Releasing the tow hook on a glider.
- Operating the airbrakes; great when you are trying to do spot landings.
- Opening and closing the bomb bay doors on a large model B52.
- Landing gears — or anything else that requires a gentle, two-way operation.

I am sure that once the full line of actuators is available, you will find a myriad of interesting applications in both RC and robotics. The PQ-12

Parts List

Qty.	Location	Description	Source
■ 1	IC1	CD4538 retriggerable multivibrator	Fairchild
■ 1	IC2	CD4013 D type flip-flop	Fairchild
■ 1	K1,K2	G6AU relay or equivalent	Omron
■ 1	LS-9	Actuator	Fircelli
■ 1	Input	Servo cable	Futaba

■ Resistors 1/4 watt, 5%, and ceramic capacitors. Values are as shown in the diagrams.

Acknowledgements

I would like to thank Ron Klopfer at Fircelli Industries, Inc., for lending me their pre-production model of the LS-9, thereby making this project far more interesting than I anticipated.

Lego is a registered trademark of Legoland, Denmark.

series includes a potentiometer allowing for feedback of the actuator's position. Full information is available on their website at www.firgelli.com

A Simple Actuator Control

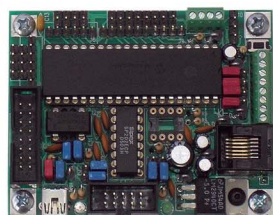
The servo alternative circuit is well suited to control the actuator. Figure 3 shows the relay output circuit with an actuator. Using two contacts of the relay shown in Figure 1, we have a means of changing the direction of the actuator by simply changing the direction of the current flow. The design is such that the actuator can be located close to the mechanical part to be operated while the electronic circuitry is elsewhere in the system. Remember that long leads should be twisted and may require bypass capacitors across the terminals to minimize the potential of interference.

Building the Alternate Servo

Standard tools and a dual beam scope are all you need to build this simple circuit. Hardwire or printed circuit, it is your choice. Figure 4 shows just how simple the layout is. Do you have a question, comment, or a better way to do it? Please feel free to email me at paul.weijers@videotron.ca **SV**

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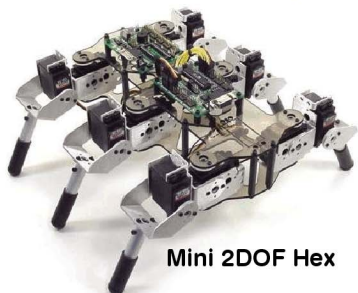
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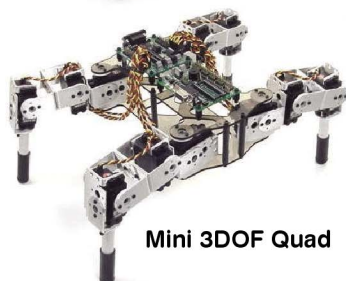
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Walking Stick



Mini 2DOF Hex



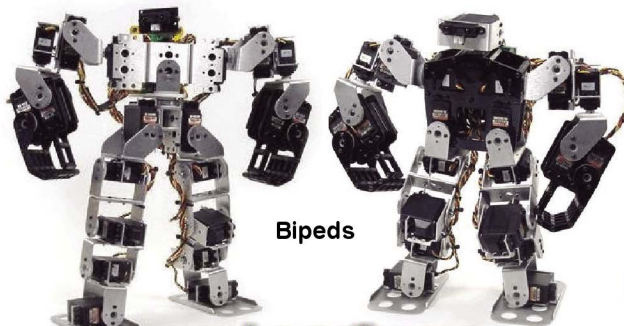
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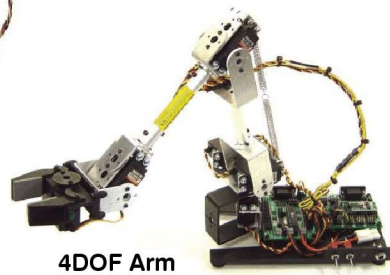
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Artificial Pneumatic Muscles (*Air Muscles*)

BY JOHN IOVINE

An air muscle is a simple pneumatic device developed in the 1950s by J.L. McKibben. Like biological muscles, air muscles contract when activated. Robotists find it interesting that air muscles provide a reasonable working copy of biological muscles. So much so that researchers can use a human skeleton with air muscles attached to the skeleton at primary biological muscle locations to study biomechanics and low-level neural properties of biological muscles (see Internet sources).

>> Applications

Air muscles have applications in robotics, biorobotics, biomechanics,

artificial limb replacement, and industry. The main reasons experimenters and hobbyists will like air muscles is because they are easy

to use (as compared to standard pneumatic cylinders) and have simple construction. Air muscles are soft, lightweight, and compliant, and have a high power-to-weight ratio (400:1). They can be twisted axially and used on unaligned mounting and provide contractive force around bends (see the Robot Wars section near the end of this article). Air muscles may also be used underwater.

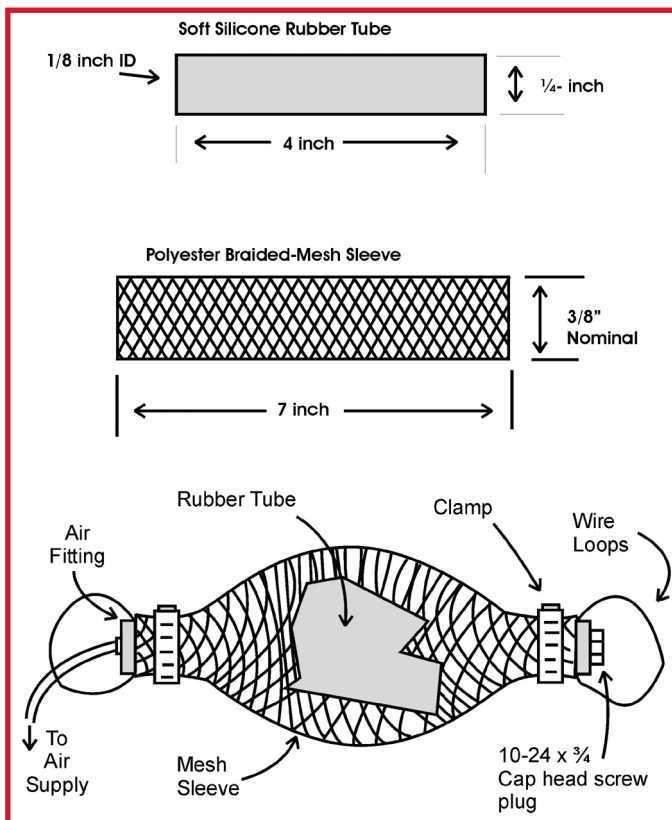
>> How Air Muscles Work

There are two primary components to the air muscle: a soft stretchable inner rubber tube and a braided polyester mesh sleeve (see Figure 1). The rubber tube is called an internal bladder, and is positioned inside the braided mesh sleeve.

To complete the air muscle, you need an air fitting on one end and then two mechanical fittings (loops) on each end of the air muscle. This allows you to attach the air muscle to devices. The clamps in Figure 1 are made from 24-gauge wire, tightly wrapped and twisted.

When the internal bladder is pressurized, it expands and pushes against the inside of the braided mesh sleeve, forcing the diameter of the braided mesh to expand. The physical characteristic of the mesh sleeve is that it contracts in proportion to the degree its diameter is forced to increase. This produces the contractive force of the air muscle.

To operate properly, it is important that the air muscle be in a stretched or loaded position when it's in a resting



>> **FIGURE 1. Components of an Air Muscle.**

state. If it isn't, there will be little — if any — contraction when activated (see Figure 2). Typically, the air muscle can contract to approximately 25 percent of its length.

The illustration of the contracted air muscle in Figure 2 is greatly exaggerated. When the air muscle contracts, its diameter thickens equally along its length, then shortens, as described. Air muscles typically do not develop a large bulge in the center when contracted, however, for purposes of illustration, it is shown this way.

>> Air Pressure

Air muscles require a source of compressed gas (usually air). The air muscle we will build operates at approximately 50 psi. Air pressure can be easily generated by using a small bicycle pump with an air pressure gauge, or get a small air tank that can be filled up at a local gas station. If you use an air tank, make sure it is equipped with an adjustable air pressure regulator; this will prevent over pressurizing the air muscle.

>> Making an Air Muscle Yourself

Air muscles are available commercially from Shadow Robotics in the U.K., in a variety of sizes. For experimental purposes, it's pretty easy to make your own air muscle in whatever size you require.

The inner tube is made from soft silicone tubing, approximately 1/4" OD and 1/8" ID (see the Parts List). Go to a local pet shop that sells aquarium supplies and purchase a small quantity of clear PVC tubing (same size as the silicone tubing, but less flexible and tougher). Pick up a few aquarium air valves and couplings, too.

Many electronic distributors sell the polyester braided mesh sleeve. The braided sleeve is used as a flexible conduit for electrical

>> **FIGURE 2. Basic Function of the Air Muscle.**

wiring. Purchase a small quantity (six feet) of 3/8" diameter.

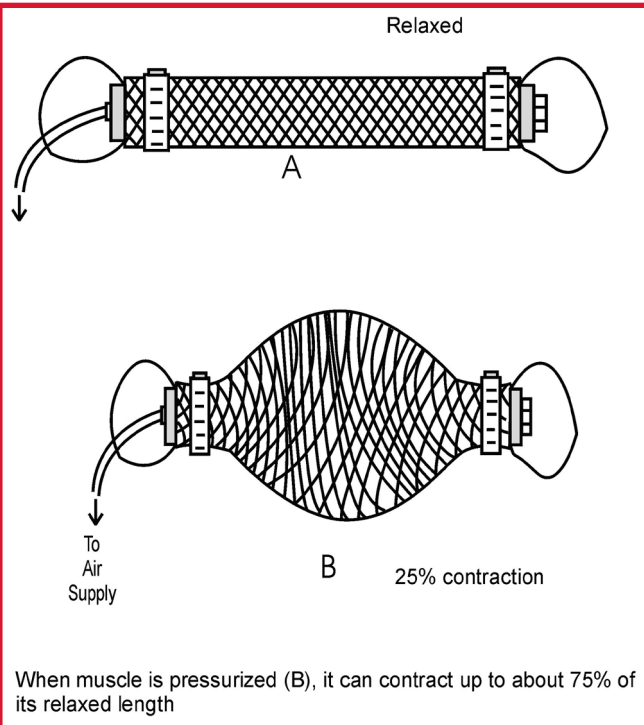
Also purchase a few 3/8" long 10-24 screws and a small quantity of 24-gauge galvanized wire available at local hardware stores.

Cut a four-inch length of silicon tubing. Insert the 10-24 screw in one end of the tube. Insert an aquarium air coupling in the other end of the tube (see Figure 3).

Cut a seven-inch length of 3/8" braided mesh sleeve. To prevent the ends of the sleeve from fraying and coming apart, singe the ends with a match or candle flame (see Figure 4). The idea here is to just singe the ends of the polyester sleeve. Don't go too far or you will melt too much of it.

Insert the rubber tube inside the braided sleeve. Align one end of the sleeve with the bottom of the head on the 10-24 screw in the rubber tube. Wrap a piece of 24-gauge wire three or four times around the end, capturing the sleeve, tubing, and threaded portion of the 10-24 screw. Then twist the ends of the wire together. Use a pair of pliers to get this as tight as possible. Cut off any excess wire (see Figure 5).

To finish the other side, push down the sleeve until it is aligned with the rubber tube on the air coupling. Wrap a piece of 24-gauge wire around this end,



tighten the wire with pliers, then cut off any excess (see Figure 6). At this point, you may want to pressurize the air muscle to insure the two fittings do not leak. Since the air muscle is not loaded, only use a pressure of 20 psi. If there are any air

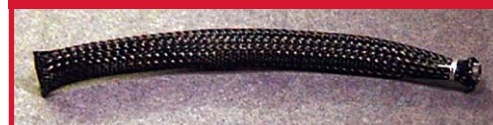
>> **FIGURE 3. Inner bladder tube.**



>> **FIGURE 4. Sealing end of polyester braided mesh.**



>> **FIGURE 5. Tying one end of braided mesh to bladder tube.**



>> **FIGURE 6. Tying opposite end of braided mesh to air fitting.**





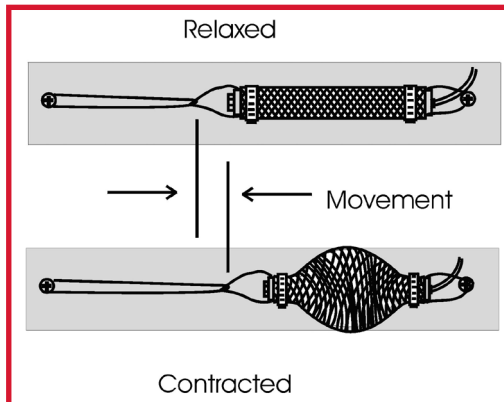
>> FIGURE 7. Wire loop.



>> FIGURE 8. Securing wire loop to air muscle.

leaks, try tightening the 24-gauge wire a bit more.

Cut two 14-inch lengths of the galvanized wire. We will use these to make the mechanical loops. Fold the wire in half to double it. Form a one-inch loop from the middle of the wire and twist the wire at the bottom of the loop (see Figure 7). Next, wire-wrap the loop to the end of the air muscle, as shown in Figure 8. Do the same to the other side. Pull on the loops to insure that



they are secure.

>> Testing the Air Muscle

The first test to perform is a simple static test. Wear eye protection when pressurizing the air muscle. Attach one end of the air muscle to a stationary object using the loop. At the other end, hang about five to six pounds of material to the air muscle using the other loop. This weight will load the air muscle, causing it to stretch. Pressurize the air muscle with approximately 50 psi. The air muscle should contract and easily lift the weight. While it's pressurized, check it again for any air leakage.

>> First Mechanical Device

This first device illustrates the function of and measures the contraction obtained with the air muscle (see Figure 9). The air muscle is mounted to a

>> FIGURE 9. First mechanical device – testing air muscle movement.

piece of 1" x 2" lumber approximately 16" long. One end of the air muscle loop is placed over a wood screw secured into the wood. A thick rubberband is put through the air muscle loop on the other end. The rubber band is pulled until the air muscle is just fully extended. Do not over extend or pull the rubberband any farther as this will add

additional resistance to the air muscle and won't contribute to its function. A woodscrew is secured into the wood at this point and the rubberband is looped over the screw.

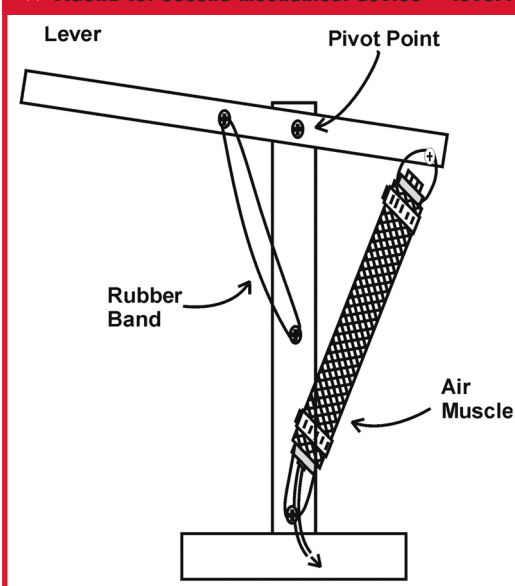
When you pressurize the air muscle, you can measure its contraction. Release the air pressure from the muscle and it should extend into its relaxed state.

>> Second Mechanical Device

A mechanical drawing of a simple lever is shown in Figure 10 with a photo shown in Figure 11. Activating the air muscle causes the lever to rise. In this lever, we are using a number of rubberbands to load the air muscle.

Figure 12 illustrates how two air muscles can be configured to provide a counter force or load for each other.

>> FIGURE 10. Second mechanical device – lever.



>> Controlling the Air Muscle

Typically, three-way air valves are used to control the air muscle (see Figure 13). To activate the air muscle, valve #2 is opened. This causes the air muscle to contract. Once activated, the #2 valve may be closed without impacting the state of the air muscle. The air muscle will stay in a

>> FIGURE 11. Photograph of lever.

contracted state. To relax the air muscle, the air pressure must be vented by opening valve #1.

A three-way stopcock air valve may be purchased (see Figure 14) to allow you to control the air muscle manually. A three-way valve may be constructed using two one-way air valves. Small plastic aquarium valves purchased at a local pet shop work quite well. However, they are not rated for work at 50 psi, so wear eye protection, just in case they pop apart from the air pressure.

>> Electronic Control System

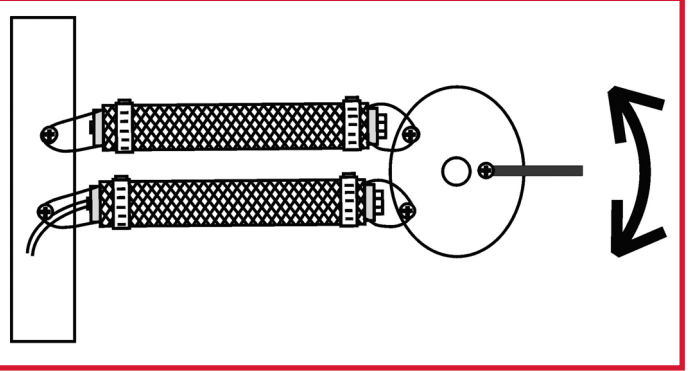
Manual valves work great for testing and learning about air muscles. To build a robot or industrial device, we need electronic control of the air muscle. Fortunately, this is not difficult.

There are a number of electrical solenoid air valves available. I prefer the Isonic valves from Mead Fluid Dynamics. These are three-way air valves that are activated using five volts (see Figure 14).

The three-way Isonic valves automatically vent the air muscle (through the back) when it is deactivated. To see how this particular valve works, go back to Figure 12. In the Isonic valve, valve #1 is normally open (this is the vent,

>> **FIGURE 12.**
Configuration of two counterbalancing air muscles.

located in the back of the valve). Valve #2 is normally closed; this is labeled "In" in Figure 14. The air stream to the air muscle is labeled "Out" in Figure 14. When the electronic valve is activated, valve #2 opens, allowing air pressure to the air muscle, and valve #1 closes. When deactivated, each valve changes state:



WEBLINKS

Visit the following links for more information on air muscles:

Cricket Micro-robot

http://biorobots.cwru.edu/projects/c_mrobot/c_mrobot.htm

Construction of McKibben Artificial Muscles

http://brl.ee.washington.edu/Research_Past/Biologically_Based/Device_01_McKibben/McKibben_Construction.html

Powered Prosthetics Project

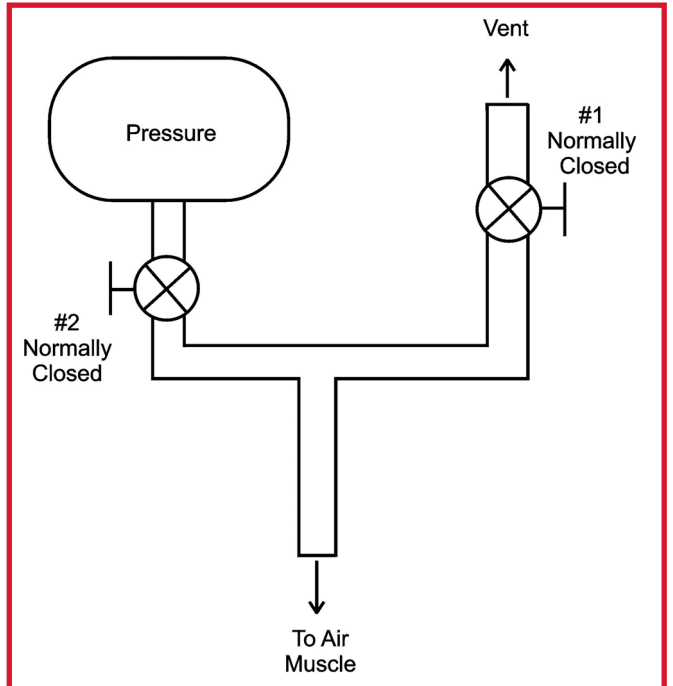
http://brl.ee.washington.edu/Research_Past/Biologically_Based/Project_02_Prosthetics/Powered_Prosthetics.html

Pneumatic Robot Home Page

www.ks.uiuc.edu/Research/Neural/robot.html

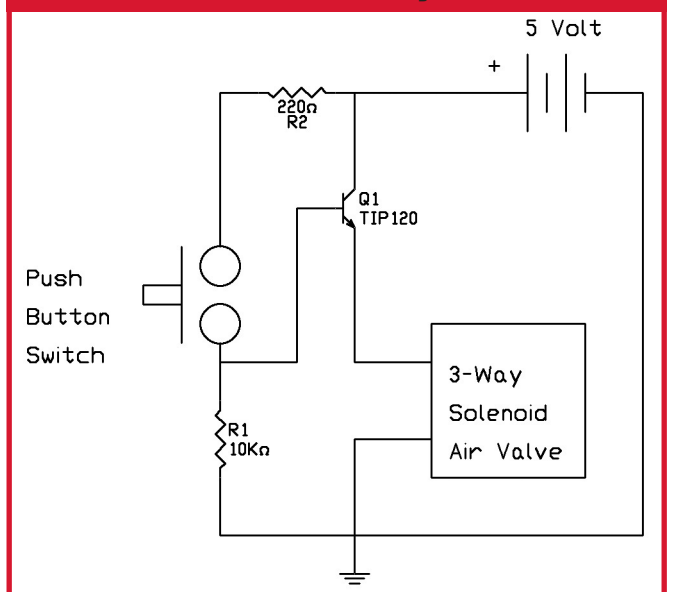
Anthroform Arm Project

http://brl.ee.washington.edu/Research_Past/Biologically_Based/Project_01_Arm/Anthroform_Arm.html

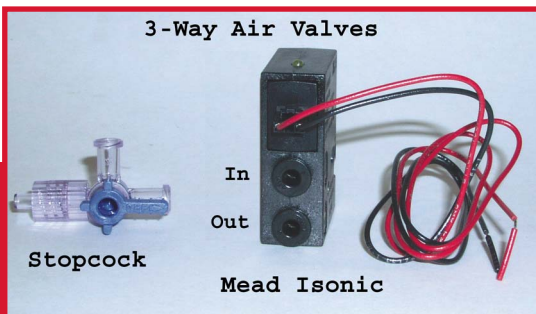


>> **FIGURE 13.** Three-way valve operation.

>> **FIGURE 15.** Schematic for controlling electrical air valve.



>> **FIGURE 14.**
Manual and electrical three-way valves.



PARTS LIST

>> Soft Silicon tubing PN# 75-300-016

>> Barnant Company
Dept. 77-3397
Chicago, IL 60678-3397
Tel: 847-381-7050

>> Local Suppliers
Polyester braided mesh, air tubing, air valves, air couplings, 24-gauge galvanized wire.

Manual or Electric Control

>> 5 VDC Mead Isonic three-way solenoid air valve
>> 10K 1/4 watt resistor
>> 220 ohm 1/4 watt resistor
>> Pushbutton switch (normally open)

Commercial air muscles available from:

>> Shadow Robot Company Ltd.
251 Liverpool Road
London N1 1LX UK
Tel: +44 (0) 20 7700 2487
www.shadow.org.uk/index.shtml

valve #1 opens, venting the air muscles air pressure; and valve #2 closes, separating the air supply from the air muscle.

The front of the Isonic air valve has two quick connects-disconnects for air tubing. This particular air valve uses semi-ridged 4 mm tubing, which is a good size for running air to the air muscle. To use the quick connect, simply push the air tubing into the hole, to lock it in. To disconnect, hold the valve flange to the valve body with your fingers and pull the tubing out.

Figure 15 is a simple manual schematic for a five-volt control circuit for the Isonic valve.

>> Going Further

Using pressurized air is an inconvenience, but one that may be overcome. For instance, at Case Western Reserve University a team of faculty and students are building a

cricket micro-robot that utilizes air muscles for walking and jumping. The micro-robot will walk and jump just like its biological counterpart. What makes this project so interesting is that the micro-robot is no larger than 5 cm (two inches) in any dimension. To power the air muscles, the team made a micro-pump that supplies 35 psi for the muscles.

>> Robot Wars

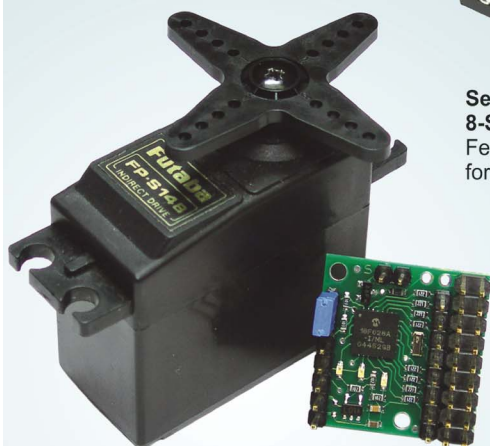
Many of the robots used in the original Robot Wars series used pneumatic devices and flippers to turn over competing robots. It is conceivable to substitute air muscles for pneumatic cylinders in these robots and thereby improve the strength-to-weight ratio. In addition, alignment for these flexible pneumatic devices is very forgiving. This allows the builder easier construction since the robot may be designed with far more open tolerances. **SV**

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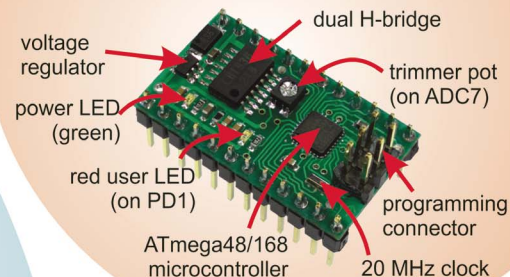
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The Baby Orangutan is a compact robot controller based on an AVR microcontroller, with a free C compiler available. The dual motor driver allows bidirectional control of two DC motors or control of one stepper motor. With its 1.2" x 0.7" outline, the Baby Orangutan can be the primary controller of a small robot or an auxiliary controller on a larger system. #0215 - #0218: **\$24.95 - \$29.95**



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Rubberbands

by Jack Buffington

How to Communicate Better With Inexpensive IR Modules

and BAILING WIRE



Have you ever thought about building a group of cooperative robots that collectively could accomplish tasks? One important aspect of creating robots like this is figuring out how they should communicate with each other. While there are various ways to accomplish this task, what is described in this column is likely to be the most inexpensive and easy-to-implement solution. It uses one infrared (IR) LED and one modulated IR receiver. Both of these parts are readily available from a variety of sources.

You might be wondering why you would want to modulate your infrared signal. It would seem logical that you could simply detect the presence or absence of infrared light and be done with this whole communications thing. Of course, if it were that simple then this column would be over with.

The light that LEDs output is tightly centered on a specific frequency so you might also think that putting a narrow band infrared filter in front of your sensor would eliminate everything but the infrared light. This is actually true, but the bad news is that infrared light can be found pretty much everywhere that you can see other light.

If your sensor happened to be a video camera, you would see everything in the environment that you are in as if you were looking at it on a black and white TV under normal light. This is why you need to modulate your infrared light source. By searching for a flickering source of light of the right frequency and the right wavelength, you can be reason-

ably certain that you are really detecting the correct signal. This sounds like a difficult task but, in reality, there are some very cost-effective parts out there that do exactly this for you.

They are usually used in remote controlled devices such as your TV or home stereo. These devices are incredibly simple to use. They are three terminal devices. Two of the pins connect to +5 volts and ground and the third goes high when a signal is detected. Although there are a variety of parts available, the one used here is the PNA4602, which can be purchased from Solarbotics for only \$1.50. That price should be within the budget of even the most cash-starved roboticist, which makes it an attractive part to use.

Figure 1 shows a photo of the PNA4602. The part is black to our eyes but is transparent to infrared light. Figure 2 shows an internal diagram of the PNA4602. The small diode on the bottom left is the actual sensor in the unit. All of the other parts massage the output of that sensor into a clean output signal.

First the signal is amplified, then it is passed through a capacitor. The capacitor removes any DC offset to the signal caused by ambient light. Next it

goes through another amplifier that adjusts the output based on how strong the signal is already using an auto gain control circuit. Next, the signal is fed into a band pass filter. This gets rid of all frequencies except for the one that we are looking for.

In the case of the PNA4602, this frequency is 38 kHz. It is interesting to note that the reason that 38 kHz was chosen is simply because these sensors evolved from early TV remote controls that used ultrasonic sensors instead of infrared sensors. These sensors sent out their data at the resonant frequency of

Figure 1. The PNA4602.

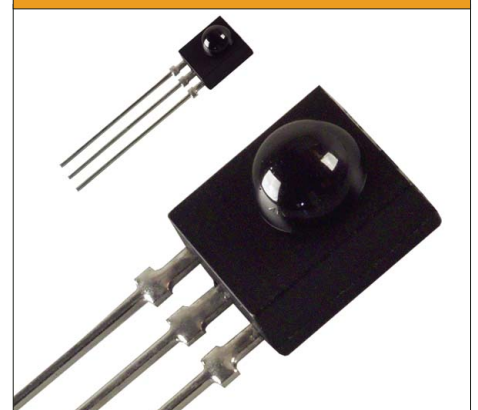
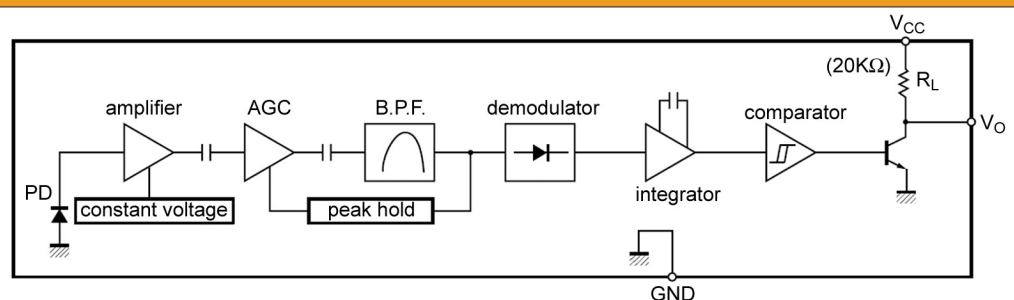


Figure 2. Internal diagram of the PNA4602.



TECH TIDBIT: SCHMITT TRIGGERS

A Schmitt trigger is a useful device that takes an input voltage and compares it to two internal voltages. If the signal rises above the higher voltage, then the Schmitt trigger will output a high signal. If the signal falls below the lower voltage, then the output will go low. Schmitt triggers are useful when you need a binary output but have a noisy input. The difference between the two reference voltages gives you some immunity to noise. Logic symbols for parts that are of the Schmitt trigger variety will usually be drawn with the symbol shown here inside of them.



the ultrasonic transducer, which was at 30 kHz. The ultrasonic sensors would sometimes change your channel for you if a car passed by with squeaky brakes or something else produced a sound that was close to the frequency of the ultrasonic remote. In short, 38 kHz is simply a holdover from dead technology.

LEDs can be switched on and off incredibly rapidly and if you are ambitious enough to build your own detector based on the circuit in Figure 2, then you can achieve much higher data rates. Going back to the circuit in Figure 2, the signal is now fed through a diode. This changes the signal from an AC signal to a DC signal that consists of only the top portion of the original waveform. Now it goes

through an integrator, which could be as simple as a capacitor connected between the signal and ground or it could be an actual amplifier as shown in the diagram.

The result is a roughly constant DC voltage that will be proportional to the amplitude of the modulated signal. This voltage is sent through a Schmitt trigger comparator and then to an output circuit. In short, all of this gives you a nice, clean output signal that is either high or low.

Making the Magic Happen

Now that you know how the signals are decoded, let's look at how to send them. A simple circuit to create these pulses is shown in Figure 3. It uses a 555 timer chip and three other components to put out a square wave of approximately 38 kHz with roughly a 50% duty cycle. By using a transistor to connect and disconnect the output of this signal to an IR LED, you could send data to the PNA4602. Let's look at how you can drive the transistor to send serial data.

Looking at the data sheet for the PNA4602, we can see that the detector typically needs a minimum high and low pulse of at least 400 μ s each. This means that we could send a 2500-baud signal through this link. Of course, they also list a maximum high and low pulse of 600 μ s. This would allow us to send a 1667-baud signal across the link. These speeds are pretty low if you want to send a lot of data but are just fine for many signals that would allow your robots to collaborate, which could be as simple as a single byte.

If you were using a processor that has a hardware serial port, you could simply connect the RX pin to the PNA4602 and the TX pin to the base of the transistor that connects and disconnects the 555's output to the IR LED. Done! This is definitely the easiest way.

If you are using a processor that doesn't have a hardware serial port, then you will have

to do things in software. There are various ways to accomplish this task. The first would be to write a subroutine that you passed a byte to and it would transmit the byte. Of course, this would suck up 100% of your processor while it was doing this.

If you have nothing pressing that needs to be calculated, then this is a perfectly acceptable method of transmitting data. Of course, since you have a processor available, you might as well generate the 38 kHz signal with the processor and ditch the 555 timer. Besides a lower parts count, you would also benefit in another way. Unless you use high quality components, the output signal from a 555 timer will tend to drift to different frequencies depending on the temperature. Your processor will have a much more stable output frequency.

The problem with having a subroutine that sends your serial data is that you can't send and receive at the same time. You would have to have another routine that you call to receive a byte of data. It would hang in a big loop until it found a byte of data and then return. This is pretty wasteful of processing power. Let's look at another way to accomplish sending and receiving our serial data.

We could do it with interrupts. What is an interrupt, you ask? Most processors have interrupts. They are events that cause the processor to drop what it is doing at the moment, store any variables that it is working with, and then take care of whatever caused the interrupt. When the interrupt service is done taking care of its work, then the processor goes back to what it was doing before the interrupt. In this case, we would be using a timer interrupt.

We would set things up so that the timer overflowed at a rate that was some multiple of your desired baud rate. There would be two state machines inside of the interrupt routine. The first would be the transmit state machine. This routine would increment a counter every time that the interrupt routine was called. If you were having the interrupt routine happen at four times the rate of the baud rate, then you would divide the counter by four and use that as the index to what bit you were currently working on. You would generally want to transmit a start bit, then eight data bits, then

RESOURCES

Solarbotics

www.solarbotics.com

Sells the IR receiver, 555 timer chips, and IR LEDs

<http://hyperphysics.phy-astr.gsu.edu/hbase/electronic/schmitt.html>

More about Schmitt Triggers

SERVO Magazine

www.servomagazine.com

Find some example code for interrupt-driven serial data.

Figure 3. A 555 timer circuit that produces approximately a 38 kHz square wave with a 50% duty cycle.

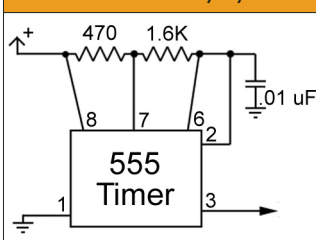
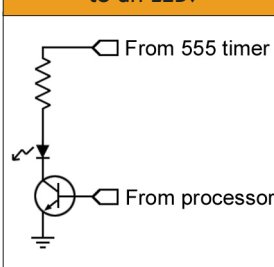


Figure 4. Connecting the 555 timer and processor to an LED.



a stop bit, but since you aren't using a real serial port, the order and structure of the bits is up to you.

To receive is slightly more difficult. You will need to look for a pattern that matches with the data that you are sending. Let's assume that you are following the typical RS232 data format. In this case, your receive function would start by looking for the start bit. Your start bit will always be high. After a high bit is received, the next three times the interrupt happens, the interrupt routine must see a high bit, as well. If it does, then the start bit will have been found. Now it will store groups of four bits as it receives them. If at least three of the four bits are of the same polarity in each group, then it will consider them to constitute a valid received bit. If two are high and two are low, then it will assume that it is receiving noise and go back to looking for a start bit. If it receives eight bits and a stop bit successfully, then it will store the byte in a buffer, increment the buffer depth, and set a flag to say that there is data in the receive buffer.

The point of sampling each bit four times is to try to prevent any noise issues. If you are extremely limited on processing power, you might opt to live dangerously and look for a valid start bit and then only sample once for each successive bit in the middle of when it should be received.

The interrupt routines that were just described work great if you happen to use the 555 timer circuit that was described earlier. If you wanted to generate the 38 kHz signal with your processor, then you could have two interrupt sources to generate your serial data. One would happen at a multiple of the baud rate as was just described and one would happen at 76 kHz. The 76 kHz interrupt would be enabled and disabled by the first interrupt depending on whether a high or low bit was being sent. This interrupt would generate the 38 kHz signal. Of course, we are then getting into a situation where we are sucking up a lot of processor power again.

If you have been looking for a good excuse to play around with one of the tiny processors that have been coming out recently — such as the PIC10F series of six-pin processors — but have been stumped about what they could actually be used for, here is a good application. You could share a common clock between your main processor and the tiny processor and then run normal serial data into the tiny processor, which would convert it into nothing or a 38 kHz signal.

The cost would roughly be similar to a 555 timer chip and its components, but the accuracy would be much higher. You would also have the ability to possibly offload a little extra processing onto the tiny processor, which could make it even more valuable to your project.

Okay, you now have a way to send and receive serial data. What happens if two robots try to send data at the same time? It's called a collision. Collisions are unavoidable unless you have some sort of scheme where each robot transmits in turn, but this can be bad if a robot wanders out of range and misses its turn or doesn't hear one of the others before it.

A way that you can deal with collisions is to simply have the receiver send a positive response if it successfully received the data. If a sender doesn't receive a response, then it should delay a random amount of time and then retransmit. Eventually the message should get through.

Be aware that the more robots that can potentially try to transmit, the more likely you will have collisions. There will be some point where communication will be difficult if you have too many senders competing for time. That is something for a future column though. For now, just be aware that this problem exists if you are making particularly chatty robots.

Simple communication between your robots using a strategy such as this can be a useful thing. It opens up the possibility of having multiple robots work together cooperatively to complete a common task. Cooperative robotics isn't something that is explored very often by hobbyists. It is usually something that you see at the university level. Hobbyists are usually trying to overcome the obstacles of just navigating, but if you have already reached that level of success, this is something that you might consider.

This could also be a good project for a group of people since the labor of actually building the robots would be split among multiple people. Perhaps this is something that your local robotics club might be interested in. Just think of all of the things that you could accomplish, such as faster cleaning of an area by alerting other robots of messy areas or long-range communication by creating a chain of robots that string themselves out so that they can only hear their immediate neighbors.

What if you created sensor robots that spread themselves over an area to sense something that no single robot could by itself. The possibilities are endless. What will you do? **SV**

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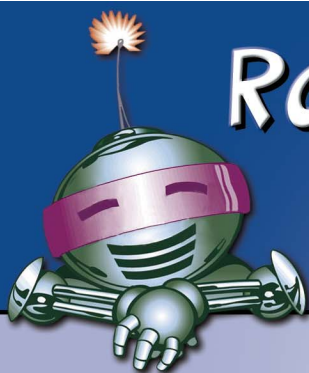
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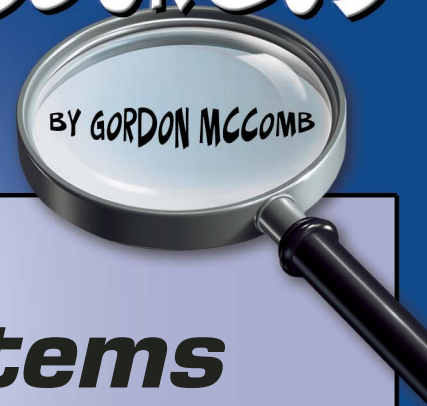
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ROBOTICS RESOURCES

Tune in each month for a heads-up on where to get all of your "robotics resources" for the best prices!



Pressure Actuation Systems

Motors are amazingly powerful for their size. Imagine: something the size of a walnut can propel a one pound robot across the room. But if that seems incredible to you, consider the amount of work that a pressure actuation system can produce.

Pressure is provided in the form of air or other gas or some kind of liquid. Air pressure systems are called *pneumatic*; liquid pressure systems are called *hydraulic*. Both are more bulky than motor actuators, but they can also provide a lot more power — *lots* more!

If you've ever watched a bulldozer go about moving dirt from pile to pile, you've seen hydraulic power at work. And, while you drive, you use it every day when you press down on the brake pedal. Similarly, pneumatic power uses air pressure to move linkages. Pneumatic systems are cleaner than hydraulic systems, but all things considered, aren't quite as powerful.

In this month's Robotics Resources, we'll take a look at small-scale pressure systems suitable for use in robotics. While pneumatic and hydraulic components can be frightfully expensive when purchased new, there's quite a bit of it available on the surplus market. We'll look at where you can find information from manufacturers on using pneumatics and hydraulics, and what you need to put a system together. The Sources section of this month's column includes a number of surplus outfits where you can find power system components

on the cheap.

Parts Is Parts

Hydraulic and pneumatic systems are pressurized using a pump or compressor. A pump is used for hydraulic systems and a compressor for air systems. The pump/compressor is typically driven by an electric motor. For air-based systems, the compressor can be part of the robot or it can be external. If external, the on-board system is charged using a compressor. The compressor puts air into a compressed-air tank — like a SCUBA tank. This provides a reservoir of air pressure. Eventually, the tank becomes depleted and must be recharged. The pressurized tank is then filled back up using the compressor.

Connected to the pump or compressor is one or more *cylinders*, which are used to move things on your robot (i.e., legs, or an arm, or finger grippers). Cylinders are constructed like medical syringes: a cylindrical body houses a piston, which moves up and down under pressure.

Cylinders come in different *bores* and *stroke length*. Bore is the diameter of the cylinder, and it directly relates to the amount of force that can be exerted by the cylinder. For the typical robotics system, the cylinders will have small bores of no more than 1/4" to 1/2". Even 1/8" is not uncommon. Stroke length (or just stroke) is when the piston moves within the cylinder. It determines the maximum distance the

piston will move when activated.

Cylinders may be *single-acting* or *double-acting*. This refers to the direction the piston may be moved under air or fluid pressure. In a single-acting cylinder, there is one inlet on one end of the cylinder. Air or fluid is forced into this inlet, which pushes the piston in the opposite direction. The piston is returned to its original position either from an external force (you manually push it back, for instance) or via a spring or other mechanism. In a double-acting cylinder, there are inlets on both ends. The piston can be forced to move in either direction, depending on which inlet is pressurized.

(Note that cylinders aren't the only form of actuator in power systems. There are also rotary actuators, which spin either a certain distance, or continuously. One common form of rotary actuator is the pneumatic motor in a pneumatic drill. A dentist's drill is a form of pneumatic rotary actuator, designed to rotate at extremely high speeds.)

The operation of the cylinder is controlled using *valves*. The valve may be manually operated, or it may be electrically operated. Electric systems use small *solenoids* that are turned on and off via a DC or AC signal. Typical of many electric solenoids is 24 VDC operation — a common voltage in machine automation applications. However, look a little further and you can also find air valve solenoids that operate at 12 VDC.

A valve is further differentiated



depending on whether it's designed for a single- or double-acting cylinder. The valve will have different inlet and outlet ports for connecting to the cylinder. Multiple valves can be used to control a cylinder, for example — one to let air (or fluid) in, and one to let it out. One-way check valves are used to route the air or fluid in one direction.

Some valves are capable of *proportional* control. That is, they can be controlled (usually via a pulse width modulated signal) to move the cylinder only part way. Ordinarily, energizing the valve will open it all the way; this causes the piston in the cylinder to move to its maximum stroke. With proportional control, you can vary the distance the piston moves.

Many hydraulic and pneumatic systems will employ a ballast or reservoir for the fluid or air. This reservoir is like a small collecting tank. One of its uses is to even out the pressure in the system. Without the reservoir, the cylinder can "throb" from the pulsating pressure delivered by the pump or compressor.

Other system components can include pressure regulators, manifolds (to split the fluid or air supply many different ways), relief valves, tubing, and more.

While hydraulic and pneumatic systems are more difficult to implement than DC motors, they offer more power. With a few hundred dollars in surplus pneumatic cylinders, hoses, fittings, solenoid valves, and a pressure supply (battery-powered pump, reservoir, etc.), you could conceivably build a hobby robot that picks up weight many times its own.

If you wish to experiment with pressure systems, I recommend first starting with pneumatics. The components are cheaper and leaking air requires no cleanup, whereas leaking hydraulic fluid is very messy.

Hydraulic fluid can be as simple as water, though, for hydraulic systems that use metal parts, this will eventually lead to rust or corrosion and leaks around the rubber seals. To protect the parts, special hydraulic fluid is used; this fluid does not mix with water and is engineered with properties that

inhibit rust. Hydraulic fluids differ in their *viscosity*, or thickness. Some types are as viscous as water, while others are more like motor oil. You match the fluid to the system you are using. The recommending fluid type is listed on the hydraulic parts you use.

Be mindful that hydraulic fluid contains toxic materials, some of which may be fatal if swallowed. Even exposure (typically long-term) to hydraulic fluids has been suspected of leading to various illnesses — even cancer. So, treat this stuff with respect. Don't spill it and make sure you design your hydraulic systems so that they do not leak. Clean up any messes immediately and avoid getting the fluid on your skin or clothing. Don't dispose of hydraulic fluid down the drain. Follow other precautions as indicated by the manufacturer of the fluid.

Learning More About Pressure Systems

So far, we've covered the veritable tip of the iceberg. There is a lot more to learn about hydraulics and pneumatics and, fortunately, the Internet

provides a great way to start.

You can begin by looking through the various applications data and white papers provided by the manufacturers of hydraulic and pneumatic components. Many companies provide free literature on their website, usually in HTML or PDF format (sometimes even as Flash animations). Some companies offer informational literature only after you register with them. Printed literature sent through the mail may carry a cost; be sure to determine if there is a fee involved before registering or ordering.

There are a few books on the subject, though most are engineering-level textbooks, some of which can be frightfully expensive. If you prefer to shop online, you can find these books through the store's search feature. Look for "pneumatic" or "hydraulic," then sift through the results. For a beginner's text on pneumatics, there's *Basic Pneumatics* (Hooper, 2003). *Hydraulics and Pneumatics: A Technicians and Engineers Guide* (Parr, 1999) covers both types of power systems. These books retail for under \$40.

Most local public and college libraries should also stock at least one

FIGURE 1. If you prefer new components, Air Cylinders Direct is among those that sell directly over the Internet.



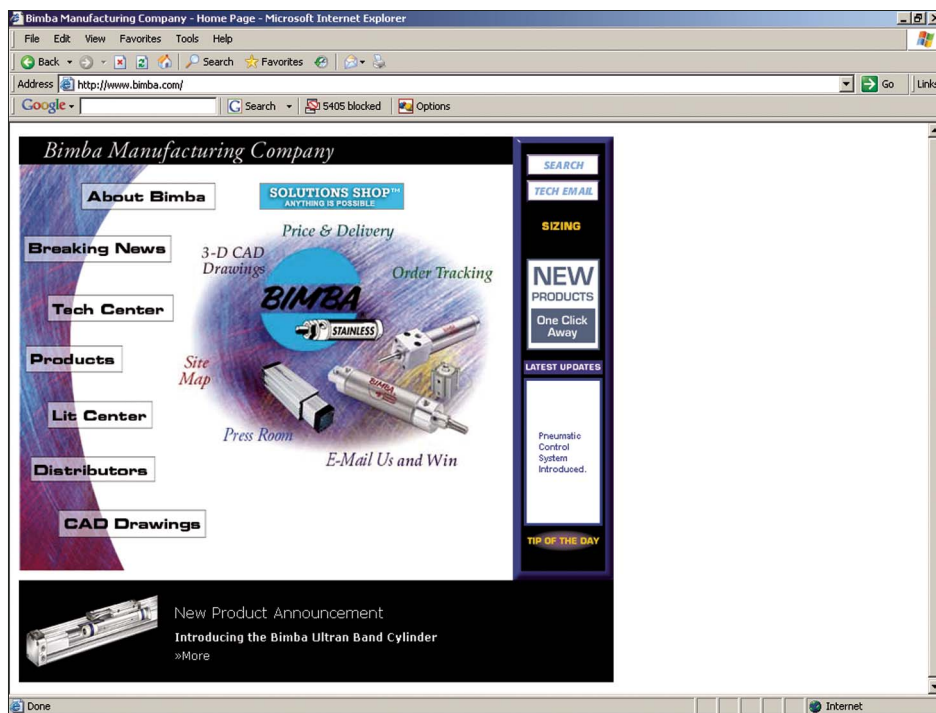


FIGURE 2. Bimba Manufacturing offers products and literature on pneumatic systems and components.

good book on the subject of power systems. Don't worry about reading an older book; the basic concepts behind hydraulics and pneumatics have not changed nearly as much as electronics, computers, and robotics!

Sources

The resources in this section specialize in pneumatic systems, including pumps, air reservoirs, air cylinders, air motors, and pressure control valves. Not listed here are pneumatic tools, which are air powered, and include the components that can be cannibalized for use in a robot. Examples of these include the air motor from a drill or retrofitting a 12-volt solenoid to operate the trigger valve from an old ratchet wrench.

The listing also includes several representative sources for paintball products. Paintball uses compressed air to shoot a pellet of paint at a target. Paintball guns and replacement parts can make for a good resource in making your own pneumatic systems for robotics. Check out Yahoo! or Google to locate other online resources

for paintball information and products.

Air Cylinders Direct
www.aircylindersdirect.com

Online shopping for myriad air components.

Airpot Corporation
www.airpot.com

Airpot makes what is known as air-damping dashpots — basically, miniature shock absorbers. Dashpots provide resistance to linear motion and are often used to reduce the sudden jarring of a lever or a bar moving in one direction or the other. The company also sells a line of small air cylinders, with the trade name Airpel.

All Electronics
www.allelectronics.com

Sometimes carries pneumatic solenoids and other subsystems. Check out their large syringes, which can be used to make simple pneumatic systems.

Applied Industrial Technologies
www.appliedindustrial.com

Industrial bearings, linear slides, gears, pulleys, pneumatics, hydraulics,

and other mechanical things. Also hosts Maintenance America, online reseller of industrial maintenance supplies and general industrial supplies, tools, paints, and adhesives.

Bimba Manufacturing Company
www.bimba.com

Bimba is one of the most recognized brands of pneumatic cylinders and associated components. Basically, if it exists in Pneumatic Land, Bimba makes and sells it. Their product is sold through distributors, but because of its popularity among designers, you'll regularly see Bimba cylinders — new and used — at surplus stores. Check surplus first, and if it's not available, consider ordering it from a Bimba rep.

C & H Sales
www.aaaim.com/CandH

Surplus mechanical and electronic equipment. Usually has a wide variety of pneumatic (some hydraulic) surplus goodies.

Clippard Minimatic, Inc.
www.clippard.com

Manufacturer of pneumatic and electronic control devices — cylinders, solenoid valves, and control electronics. Available online or through distributors.

Electronic Surplus
www.electronicsurplus.com

Occasionally carries some air cylinders and other pneumatic parts.

ENCO
www.use-enco.com

Supplier of industrial components. Online sales; large printed catalog available.

Fiero Fluid Power, Inc.
www.fierofp.com

Distributor of automation and motion control products, including Bimba brand pneumatics.

Herbach and Rademan
www.herbach.com

Surplus components, including some air cylinders and other parts.



MSC Industrial Direct Co., Inc. www.mscdirect.com

Online retailer of industrial components. Good selection of air cylinders and related pneumatic parts.

McKibben Artificial Muscles http://brl.ee.washington.edu/Research_Past/Biologically_Based/Device_01_McKibben/McKibben.html

The McKibben Artificial Muscle is a pneumatic actuator which its developers say exhibits properties found in real muscle. It's basically a rubber balloon in a plastic mesh, but while it looks simple enough, making it work right requires some planning and engineering.

Moose Industrial Surplus www.mooseindustrialsurplus.com

Surplus finds for pneumatic and

hydraulic components.

Paintball.com www.paintball.com

Forums and information about paintball products. Information on upgrading, repairing, and converting paintball air systems.

PaintBall Discounters www.paintball-discounters.com

Online sellers of paintball air pumps, air regulator, and other components. With some ingenuity, these can be adapted for use in pneumatically-powered robots.

Paintball-Online.com www.paintball-online.com

Air pumps, CO₂ and N₂ air systems, fill stations, expansion chambers and regulators, and other components for paintball. Consider for use in

making pneumatically-powered robots.

Parker Hannifin www.parker.com

Large manufacturer of industrial automation equipment, including all types of pneumatic and hydraulic components.

Surplus Center www.surpluscenter.com

Mail order surplus. Specialists in pneumatic and hydraulic components.

Toronto Surplus and Science www.torontosurplus.com

Pneumatic surplus components; mail order from Canada.

Wholesale Hydraulics www.wholesalehydraulics.com

Wholesale Hydraulics has a full line of hydraulic components. **SV**

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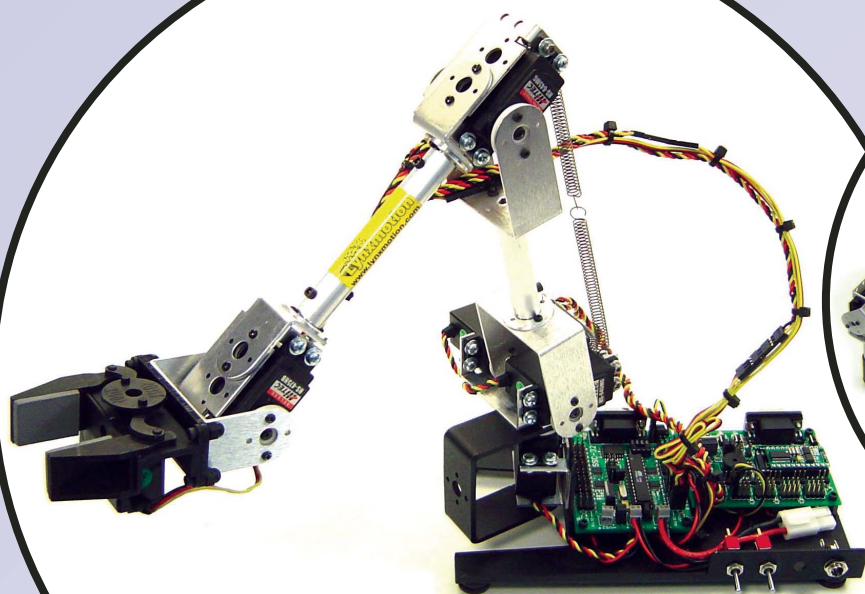
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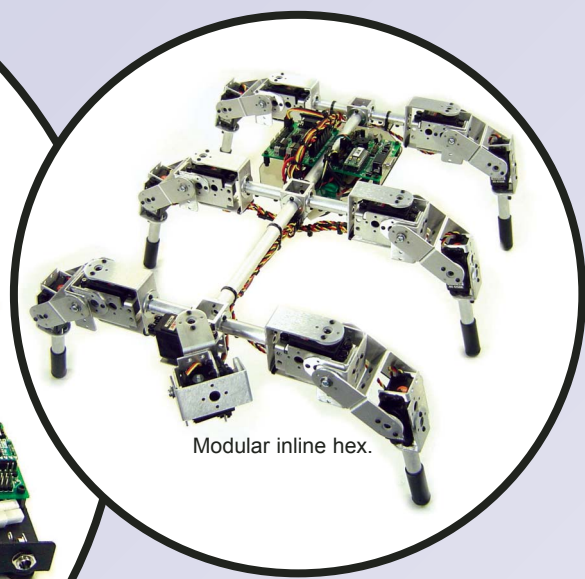
www.nubotics.com

The Way of the Walker

by Mike Keesling



Modular Arm.



Modular inline hex.

I have a propensity for walkers, particularly hexapods. So ... I am going to talk about a new way to build your walkers.

Walkers have been my holy grail, my "unobtainium," my baseline cool robot. For many years, even decades, the Lynxmotion hexapods have been at the top of my list of cool bots, but with two kids, two car payments, and a hefty Southern California mortgage, they were low on my priority list. Now that I have some dispensable income to buy them and a box of IsoPods (thanks to New Micros, Inc.) to control them, I am set up to do a lot of cool experimentation.

Recently, Jim Frye at Lynxmotion released his newest creation — a sort of robotics construction set. In the new scheme of things, you don't build a hexapod, you buy the joints and limbs to make a hexapod. Later, you can get some additional components, and repurpose your hex into an arm, or two, or six for that matter. Basically, Jim is

serving you a tasty buffet of robot joints and limbs, and it's up to all of us to dig in and build up. This is really a cool way of doing things, and the mind reels at all the possibilities.

All that flexibility unfortunately leaves me in a bit of confusion. With all this variety, my job as the reviewer is not so well defined. Initially, I wanted to show you the grand variety you can achieve with this robotics *la carte*, but alas, it is an admittedly impossible task. There is simply too much to cover. If I were to get one of each component, and extrapolate upon it, I would fill a book, not a couple pages.

To that end, I took a pragmatic approach and got my grubby little hands on a three-degree-of-freedom, six legged hex kit, and an arm kit for good measure. Again, kit is a bit of a misnomer. I ordered the legs, chassis, etc., to build these things. Later, I may

get the additional parts to build a robotic ant, for example. I really like the robot ant concept, and I have some ideas for antennae that I would like to explore. There really is no end to the variety now possible.

The kit was packed well, with all of the parts organized for easy reference. But with all the flexibility available, an instruction manual is a sort of impossibility. There truly is an infinite possible number of permutations, so common sense and the continually growing number of online tutorials will have to do. The way I look at it, if you are smart enough to spend some cash on something like this, you are smart enough to sit down and figure it out. Like an Erector Set™, there are some suggestions, but in the end, this is a construction set, not a kit.

The next thing that struck me was the materials and construction.

Bearings! Glorious bearings and lots of them. The servos are now encapsulated in aluminum shells, and bearings are provided to assure proper support for the servo horn brackets, to keep them from getting over-torqued. I have to say, this is a really nice feature. Bushings would have been fine, but bearings add a really nice touch. Bearings allow for the utmost efficiency, and if you have ever built a walker, you know that efficiency is king.

The next surprising feature was the real machined components — yes, mill work. One third of the kit is stampings, but where strength and flexibility of function are required, threaded, milled, and turned fittings are provided. Additionally, long spans are made up with extruded tubing, not folded sheet metal — another deluxe feature.

To illustrate a point, the machined components are all of a higher grade of aluminum. They provide greater strength for their mass because of this. The better aluminum is stronger, less ductile, and holds threads better. This allows for tighter tolerances and parts with more functionality.

This really is a step-up, bringing this whole buffet style “build a bot” concept to a higher level. What this says to me, is care. It shows in every detail, every component. This could have been done a lot more cheaply, but it would have sullied the whole affair. No, Lynxmotion went the deluxe route, and for this, I applaud them.

As usual, I am going to stuff a ServoPod, or IsoPod X into this thing. I put a lot of time into my inverse kinematics software to make it flexible, and since then, Randy Dumse of New Micros has inherited the code. Randy, being the code master he is, has added a lot of optimization and functionality to it. I had designed it to allow any orientation of the legs, whether they are on an in-line hexapod or a round hexapod. Randy added conditional compiling, so you just tell the code what to compile for, and it does the hard work for you.

This code offers a lot for multifunctionality, something really useful in light of how flexible the kits are. For instance, the length of the limbs is con-

figurable. In addition, the ride height, step height, stride length, and gait pattern are adjustable during walking. To change direction, the vector of motion is also settable, essentially allowing most any configuration to walk in any direction.

Most of the walking stuff out there is following a pre-canned gait, in essence leaving you with a sort of puppet. With the inverse kinematics code running, you have Cartesian control of each limb, all the while generating inverse kinematics solutions for the joints of each leg. This adds an easily controllable dynamic element to it. I am working on some other fun modes of walking, but part of it involves being able to rotate the bot’s orientation to the vector of walking.

When it comes to powering the beast, efficiency is king. For power, I am going with lithium polymer batteries. They will give me 7.2V for the servos, with the best power-to-weight ratio commercially available. Care must be taken when using these cells. Over-voltage, over-current, over-discharging can kill them — or you! If you don’t know what you are doing with them, don’t mess with them. If you do, I recommend **www.lightflightrc.com** They have been very helpful and very knowledgeable, and they sell a quality product.

If you do not want to go exotic, try some 2/3 A batteries. They are a bit heavier for their available current, so you have to sacrifice run time, but they are significantly cheaper. I have had nice batteries made at Batteries+, but you can also get packs at **www.maxamps.com** Check out the IB1200 battery packs. A single pack costs around \$20, and for that money, you can spend \$100 and have plenty of play time.

Of course, for robotic arms or experimentation, a power supply is perfectly satisfactory. I found the money I spent on my Tenma power supply was well worth it, especially during programming. By setting a current limit, you can save

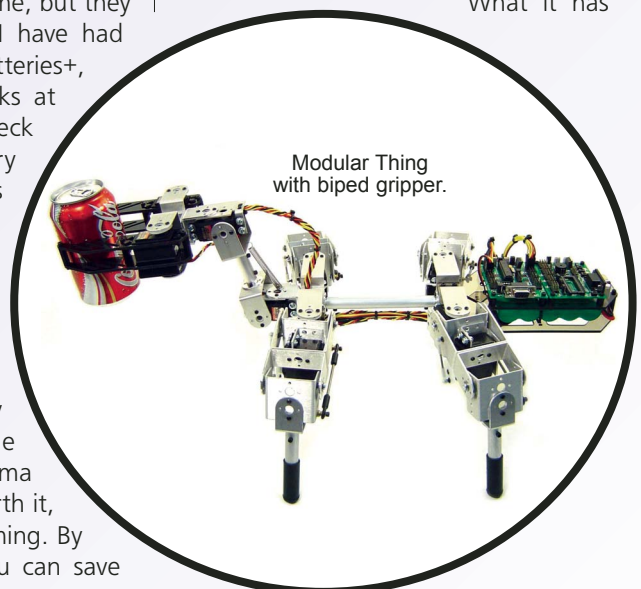
from grinding a lot of gears. (Which would you rather buy, your first high quality, regulated power supply, or a second set of servo gears after killing the first by driving them hard and fast into their end stops?)

The build went very quickly and smoothly. Parts were provided to build everything up in a variety of permutations, so there were plenty of extras. In the name of efficiency, I set my eight year old and 12 year old daughters on the task with me, and we cranked everything out in about three hours. There were no hang ups, no hitches, or gotchas. The little grunions and I had a good time doing it, and I got a chance to see smaller, nimbler fingers in action. I built up prototype parts, and handed them off to the little ones to copy. It was fun seeing how quickly they were able to crank stuff out.

The all metal construction is a vast improvement on the previous polycarbonate design, making for an even more stable platform, and its reliance on extruded tubes and turned flanges leaves it rock solid as far as hexapods go. It’s all-modular construction has me thinking about ways to do a force feedback system for the legs, without necessitating a major redesign. To that end, I am going to be ordering some more flanges, but I also want to convert it into an ant as soon as possible.

I have started construction on the robotic arm, as well. Quick and easy, solid and stable sums it up pretty well.

What it has



The Way of the Walker

me doing is thinking about the next step in software. I am going to have to code all my stuff with even more flexibility than I usually do to take advantage of the fact that everything is now so much more modular.

Overall, I couldn't be more overjoyed. The robot construction set stuff is flawless. I am left somewhat stymied, because if I touch on the subject of flexibility, I will blather on incessantly for another eight pages or more. I can't recommend this stuff more highly.

Something else I love to blather on about is robot walking. I feel that the real problem with all the robot walker kits out there is that they are basically puppets, spitting out preordained patterns of movement. My code is no exception. While I do consider many

adjustable factors like vector of motion, length of stride, leg height during the lift phase, and robot chassis height above ground, any walking it manages to do is by virtue of the fact that the ground matches the robot's expectations. In short, walking is merely a happy accident of circumstance.

At the university level, force sensors are a must. This has me thinking about how to represent walking via force feedback in code. Big questions arise like the necessity of inverse kinematics and gaits at all. I am starting to think about vector fields. Imaginary forces pulling the robot this way and that, causing reactions in the legs, all modulated by each leg's orientation, position, and circumstance.

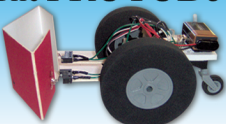
I am thinking about a distributed processing scheme, with one Plug-a-

Pod per leg. This will allow me to have analog taps for three-dimensional force sensing, plus torque monitoring on each leg. This will also allow for several pins of binary I/O, as well as some left-over analog pins. I would like to link this all up, to give each leg knowledge of its neighboring leg's position, and to share central driving forces like speed and direction of motion, as well as sharing sensory inputs.

To re-iterate, stop thinking about the robot kit you want to buy, and start thinking about the robot you want to build. This new, a la carte approach is really the way to go, and as executed by Lynxmotion, you will be entirely pleased with the results. **SV**

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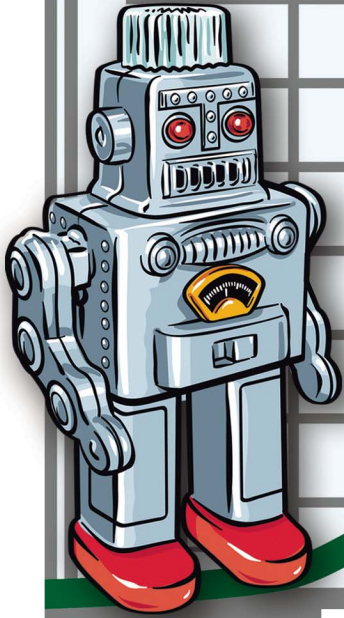
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Robotic Trends



by Dan Kara

Robotics as a Career

So, you have selected robotics as your chosen profession. Now what? Perhaps a definition of terms is in order.

No doubt about it, robotics is hot. Just count the number of column inches dedicated to the subject in the popular and professional press, or the number of minutes dedicated to all things robotic on television. Robotic competitions and conferences abound and it seems a new robotics company appears every week. The investment community, too, is standing up and taking notice. Over the last month I have personally spoken at two events focused on investment and the 'new' robotics market. What differentiates the 'new' robotics market from the 'old' robotics market was largely left undefined, but more on that later.

One byproduct of the huge amount of interest in robotics is an increased number of people who will look to robotics as their chosen profession. Robotics encompasses a number of disciplines, including mechanical and electrical engineering, along with computer science and, therefore, offers employment opportunities in

each. This, however, is only one piece of the robotics employment pie.

As the robotics industry grows and matures, additional prospects outside of engineering — but nonetheless fundamental to the growth of robotics companies and the robotics market — will emerge including career opportunities in sales and marketing, accounting and operations, as well as business development. There are also the satellite industries that will support the robotics market indirectly such as publishing (*SERVO*, for example), research and analysis, legal (intellectual property rights, incorporation assistance, etc.), public relations, and so on.

A Career in Robotics

For those who have selected robotics as their profession, the sheer number of career paths in this growing field can become overwhelming. This is especially true for engineers. Skills that

are used in the non-engineering related components of a robotics business, such as sales, or positions in the support industries — public relations serves as an example — can be applied to almost any other type of business. Engineers, however, are compensated for their specific knowledge applied to a specific problem set or product type. In the case under discussion, those product types are robots and robotic technology.

One way to maximize your chance for career success in the robotics field is to determine the current largest robotics market and then tailor your professional development into areas that serve that market. Those with a bit more foresight would ask the better question, "What will be the largest robotics market in the future?"

Before we explore future robotics markets, it would be useful to define terms. That is, let's apply a taxonomic framework to the discussion, so that we can agree as to the basic classes



Robotics encompasses a number of disciplines, including mechanical and electrical engineering, along with computer science and, therefore, offers employment opportunities in each.”

of robotics products before we agree (or more probably disagree) as to what specific market segment one should enter to achieve professional success.

What markets are we speaking of exactly? I have always found that the best place to begin anything is at the beginning. For starters, the robotics market as a whole is comprised of two distinct subgroups. These are Industrial Robotics and Service Robotics.

Industrial Robotics

The older industrial robotics segment — which was developed over the second half of the last century — consists of immobile, single task robots that have little interaction with humans or the world around them. They are termed industrial robots because until quite recently they were exclusively employed in manufacturing and factory floor automation.

The International Organization for Standardization (ISO) defines an industrial robot as "an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes." That is quite a mouthful, but connotes little to the man on the street. But you know the type. They are the robots, actually the articulated robotic arms, responsible for spot welding our cars, painting our refrigerators, and checking for irregularities in assembled products. Recently, industrial robots have been 'repurposed' (to use a West Coast term) to take on a wider range of functions.

Two Classes of Service Robots

Industrial robots differ radically from the robots and robotic technology that are classified as service robots — mobile, interactive robotic devices

with a high degree of intelligence built into them, which freely interact with humans, other robots, and their surroundings. The International Federation of Robotics defines a service robot as "a robot which operates semi or fully autonomously to perform services useful to the well being of humans and equipment, excluding manufacturing operations."

Fair enough, although service robots are often broken down further into two subgroups based on where they are employed. "Domestic Service Robots" — as their name implies — are service robots that educate, entertain, or assist in the home. These can be contrasted with "Professional Service Robots" that can be found in workplaces, public places, and other areas outside the home.

Professional Service Robotics

Professional Service Robots are semi or fully autonomous mobile robots that have applications in almost every industry — anywhere that work is repetitive, requires continuously high levels of concentration, is physically demanding, or takes place in dangerous environments. Professional Service Robots are occasionally subdivided into three additional subgroups — robots that service humans, those that service equipment, and robots that provide other autonomous functions. These

distinctions, while useful, are beyond the purview of this column (future columns will cover the Professional Service Robotics market in detail).

Examples of areas where service robots are working, or are in development, includes — but is not limited to — industrial/professional cleaning, equipment maintenance/servicing, and data acquisition. The da Vinci surgical robot (Intuitive Surgical Systems) is a service robot, along with a whole host of other medical/healthcare robots such as rehabilitation robots, and prosthetic and orthotic devices.

The Spirit and Opportunity rovers diligently working on Mars are exploration and discovery service robots, as are the Pyramid Rovers exploring inside the pyramid of Cheops. Inspection, security, construction, demolition, delivery — the list goes on and on — are all services now provided by service robots.

Robots for defense and homeland security are probably the largest subclass of service robots. Unmanned Ground Vehicles (UGV), Unmanned Underwater Vehicles (UUV), and, of course, Unmanned Aerial Vehicles (UAV), best exemplified by the Air Force's Predator UAV, are common military service robotic types. Often linked to military robots are search and rescue, fire fighting, de-mining, surveillance, and other types of public safety robots.

Personal Service Robotics

Personal Service Robots, often simply known as personal robots or consumer robots, are robots or robotic technology purchased by individual buyers (consumers) and used in the home. The personal robotics market serves the consumer market in many diverse segments (see Table 1) and is

**TABLE 1.
Classes of Personal Robots.**

- Education/Hobbyist
- Home Care/Lawn Care
- Entertainment
- Smart Toys
- Home Assistance/Assistive

typified by products such as home automation/domestic service robots (robotic vacuum cleaners and home security robots, for example), hobbyist/education robots, and entertainment robots (LEGO's Mindstorms serve as an example). Intelligent mobile toys such as WowWee Robotics' RoboSapien, along with those robots that assist the disabled and elderly in the home, also fall into the personal robotics category.

Blurred Lines

Often the distinction between personal and service robots becomes blurred or seems arbitrary. For example, when used in the home, an assistive device designed for the elderly would be classified as a personal robot, while the same technology employed in an elder care center would be categorized as a service robot. The grouping of the personal and service robots into a larger "mobile robotics" category can also add to the confusion. Perhaps the best approach is to employ the taxonomy described above when it serves a purpose, but not to get too hung up on the details.

What Next?

There you have it. The robotics industry is comprised of two major robotics market segments — Industrial Robotics and Service Robotics — with the latter encompassing two sub-groups: Professional Service Robotics and Domestic Service Robotics (Personal Robotics or Consumer Robotics). The next installment of this column will delve into what many believe will be the fastest growing and eventually the largest robotics industry segment — consumer robots. **SV**

Dan Kara is President of Robotics Trends, the producer of the RoboBusiness (www.robobusiness2006.com) and RoboNexus (www.robonex.com) conferences, and publisher of Robotics Trends (www.robotictrends.com), an online news, information, and analysis portal covering the personal, service, and mobile robotics market. He can be reached at dk@robotictrends.com

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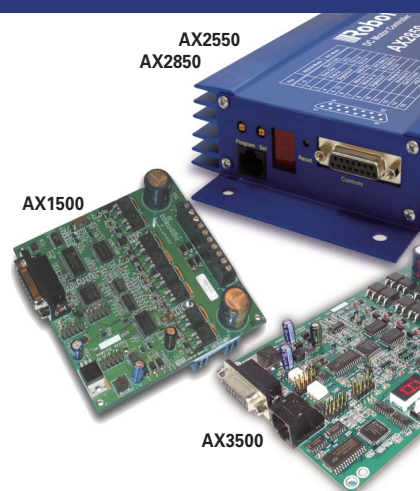
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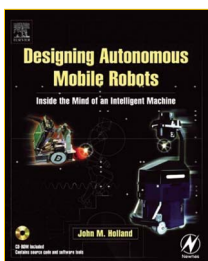
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Designing Autonomous Mobile Robots

by John Holland

Designing Autonomous

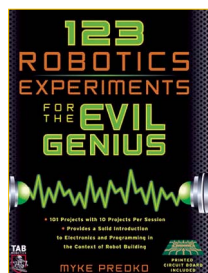
Mobile Robots introduces the reader to the fundamental concepts of this complex field. The author addresses all the pertinent topics of the electronic hardware and software of mobile robot design, with particular emphasis on the more difficult problems of control, navigation, and sensor interfacing. Covering topics such as advanced sensor fusion, control systems for a wide array of application sensors and instrumentation, and fuzzy logic applications, this volume is essential reading for engineers undertaking robotics projects, as well as undergraduate and graduate students studying robotic engineering, artificial intelligence, and cognitive science. **\$49.95**



123 Robotics Experiments for the Evil Genius

by Myke Predko

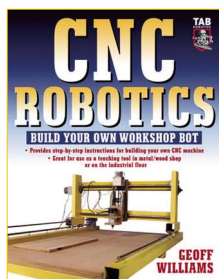
If you enjoy tinkering in your workshop and have a fascination for robotics, you'll have hours of fun working through the 123 experiments found in this innovative project book. More than just an enjoyable way to spend time, these exciting experiments also provide a solid grounding in robotics, electronics, and programming. Each experiment builds on the skills acquired in those before it so you develop a hands-on, nuts-and-bolts understanding of robotics — from the ground up. **\$25.00**



CNC Robotics

by Geoff Williams

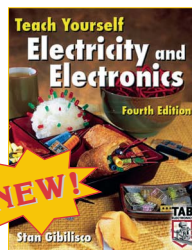
CNC Robotics gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80 percent of the price of an off-the-shelf bot — and that can be customized to suit your purposes exactly, because you designed it. Written by an accomplished workshop bot designer/builder, this book gives you all the information you'll need on CNC robotics! **\$34.95**



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by Stan Gibilisco

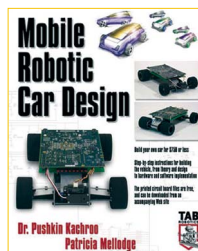
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Mobile Robotic Car Design

by Pushkin Kachroo / Patricia Melloodge

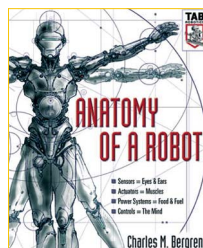
This thoughtful guide gives you complete, illustrated plans and instructions for building a 1:10-scale car robot that would cost thousands of dollars if bought off-the-shelf. *Mobile Robotic Car Design* provides serious insight into the science and art of robotics. Written by robotics experts, this book gives you a solid background in electrical and mechanical theory, and the design savvy to conceptualize, enlarge, and build robotics projects of your own. **\$29.95**



Anatomy of a Robot

by Charles Bergen

This work looks under the hood of all robotic projects, stimulating teachers, students, and hobbyists to learn more about the gamut of areas associated with control systems and robotics. It offers a unique presentation in providing both theory and philosophy in a technical, yet entertaining way. Reading *Anatomy of a Robot* is like having a robot on the operating room table. Crack open the pages and you'll be able to dissect a robot from head to toe. **\$29.95**

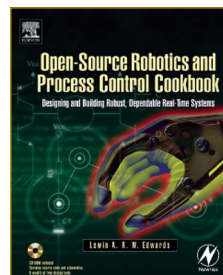


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Open-Source Robotics and Process Control Cookbook

by Lewin Edwards

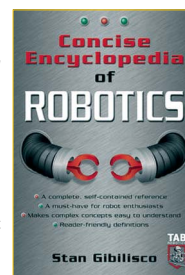
In this comprehensive guide, experienced embedded engineer and author, Lewin Edwards, demonstrates efficient and low-cost open-source design techniques, covering end-to-end robotic/process control systems using Linux as the development platform (and also as the embedded operating system), with extensive information on free compilers and other tools. Specifically, the book targets development of real-time physical system controls using Atmel AVR microcontrollers communicating with Linux-based PCs for overmonitoring. Code examples are given to provide concrete illustrations of tasks described in the text. The accompanying CD-ROM contains all the code used in the design examples, as well as useful open-source tools for robotics and process control system design. **\$49.95**



Concise Encyclopedia of Robotics

by Stan Gibilisco

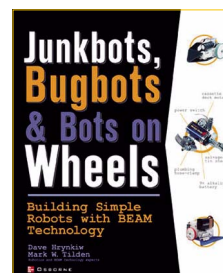
Written by an award-winning electronics author, the *Concise Encyclopedia of Robotics* delivers 400 up-to-date, easy-to-read definitions that make even complex concepts understandable. Over 150 illustrations make the information accessible at a glance and extensive cross-referencing and a comprehensive bibliography facilitate further research. **\$19.95**



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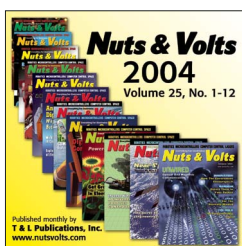
by Dave Hrynkiw / Mark W. Tilden

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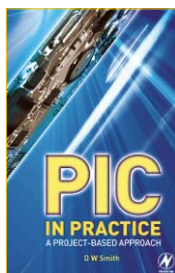
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by David W. Smith

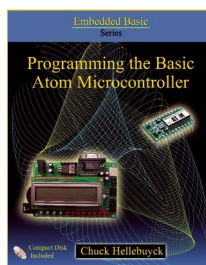
PIC in Practice is a graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling students to develop their understanding at their own pace. The book can be used at a variety of levels and the carefully graded projects make it ideal for colleges, schools, and universities. Newcomers to the PIC will find it a painless introduction, while electronics hobbyists will enjoy the practical nature of this first course in microcontrollers. **\$29.95**



Programming the Basic Atom Microcontroller

by Chuck Hellebuyck

Through his unique way of making the complicated understandable, Chuck takes the reader through the inner workings of the Basic Atom by explaining the Microchip PIC Microcontroller and its roll in the Atom module. From there, Chuck explains the various PIC based Basic Atom modules and how to use the Basic Atom compiler. Chuck then delivers 13 projects the reader can build and learn from. The reader can then use this knowledge to develop their own Basic Atom projects. **\$39.95**



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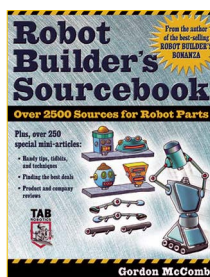
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Robot Builder's Sourcebook

by Gordon McComb

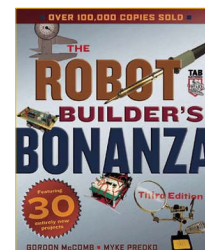
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Robot Builder's Bonanza Third Edition

by Gordon McComb / Myke Predko

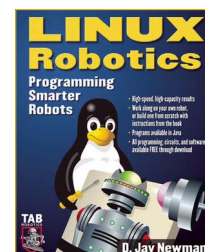
Everybody's favorite amateur robotics book is bolder and better than ever — and now features the field's "grand master" Myke Predko as the new author! Author duo McComb and Predko bring their expertise to this fully-illustrated robotics "bible" to enhance the already incomparable content on how to build — and have a universe of fun — with robots. Projects vary in complexity so everyone from novices to advanced hobbyists will find something of interest. Among the many new editions, this book features 30 completely new projects! **\$27.95**



Linux Robotics

by D. Jay Newman

If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need, plus complete training in doing original programming. **\$34.95**



From HomoSapien to RoboSapien



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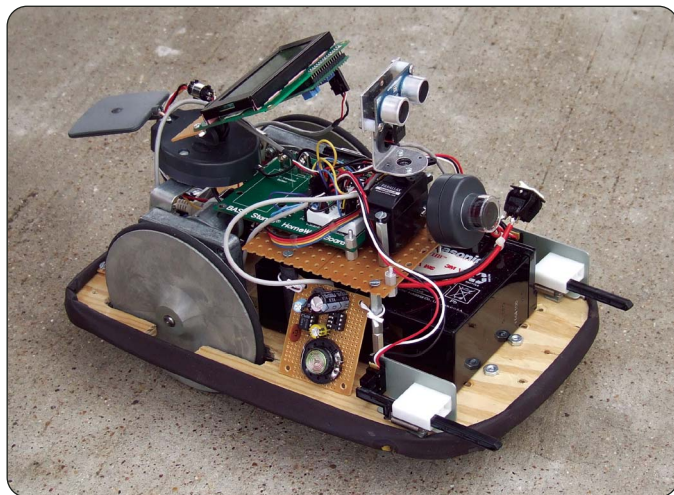
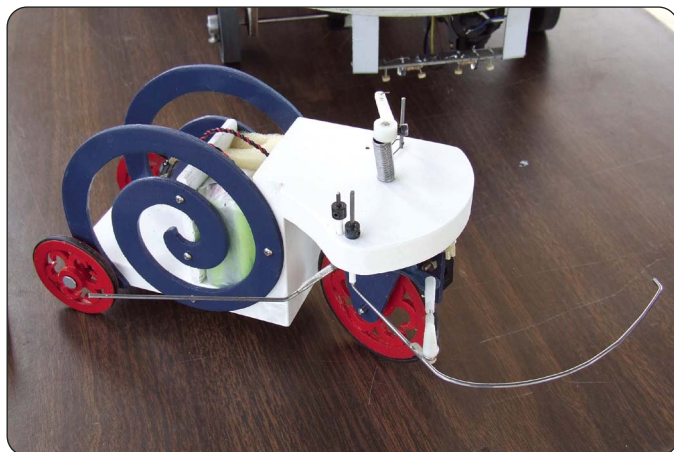
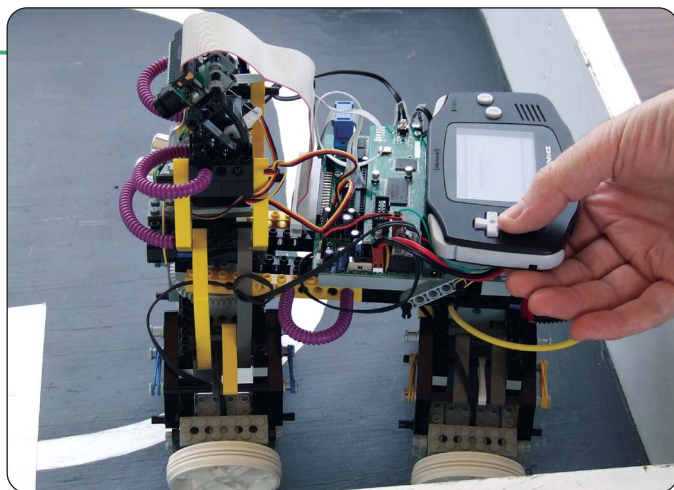
Tanner Electronics' Robot Show

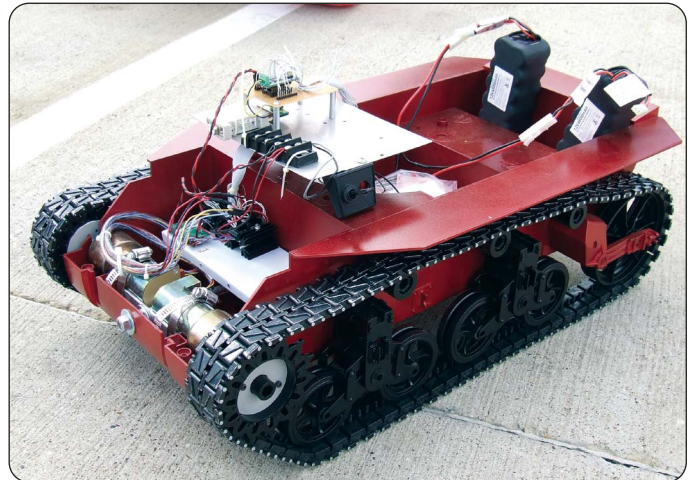
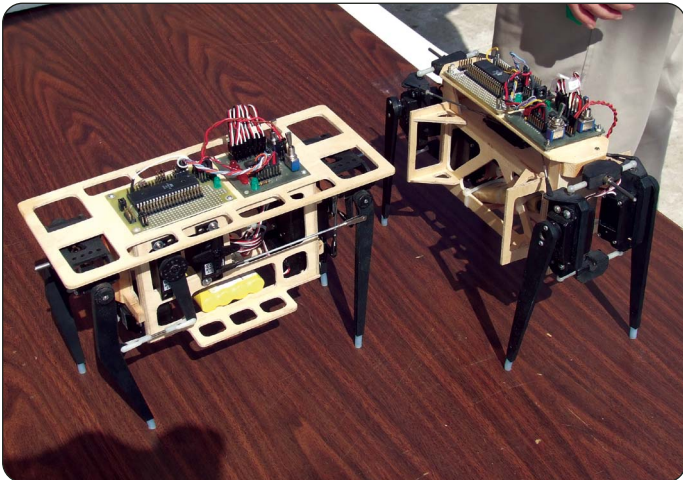
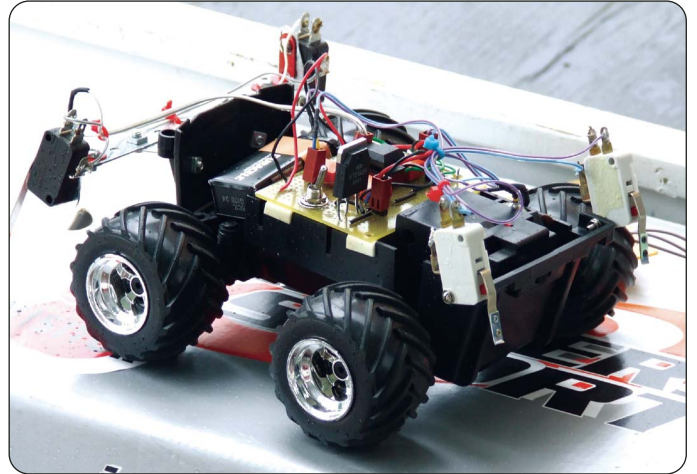
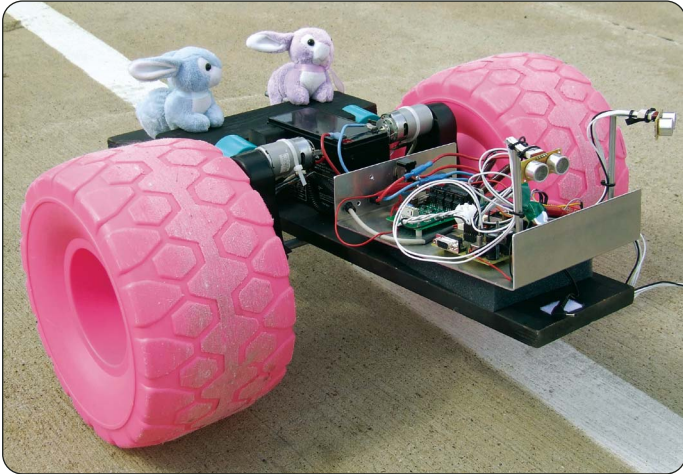
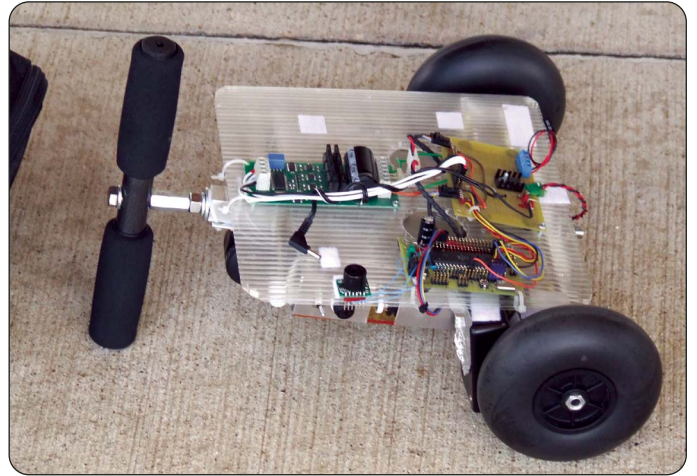
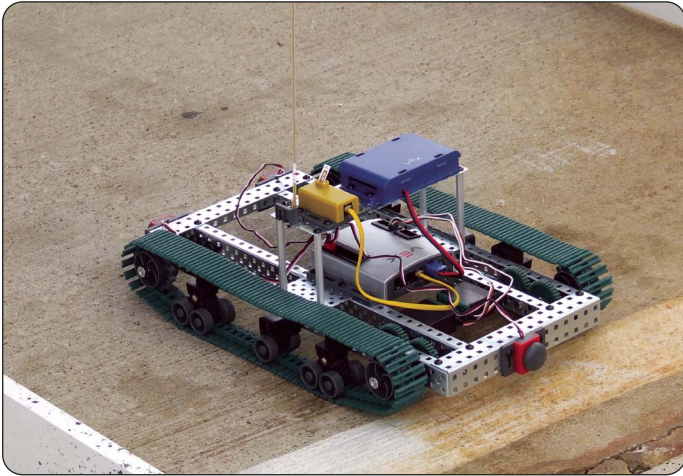
R. Steven Rainwater

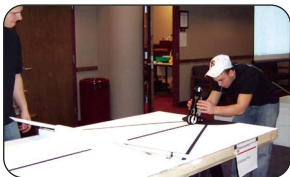
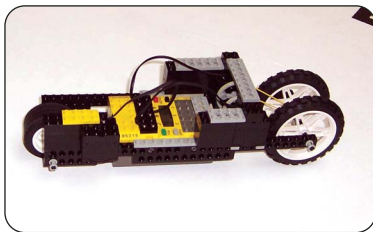
Tanner Electronics — a family owned surplus electronics business in Dallas, TX — holds an annual event called the Robot Show. Local robot groups set up tables and booths in the Tanner Electronics' parking lot.

Robot builders from all around the Dallas/Ft. Worth area bring their latest creations to show off. This year's event was cut short by a sudden thunderstorm, but not before some interesting robots were seen. If you'd like to see more, you'll find photos of the 2006 event at www.dprg.org/gallery/tanner2006/index.html

And you can see photos from the 2005 event at www.tannerelectronics.com/1strobotshow/picthumbs.html







Robotic Engineering Challenge

John Koepke

The purpose of the Robotic Engineering Challenge hosted by Juliet Junior College (JJC) is to interest students in engineering, technology, and the rapidly growing field of robotics. The student-designed robots are constructed from the LEGO ROBOLAB kit that gets provided to each team on the day of the competition. JJC believes that the ROBOLAB

system can assist in developing an interest in these technologies.

Robotic Engineering Challenge 2007 is slated for Friday, January 26, 2007 at the JJC main campus. To find out more, contact John Koepke at 815-280-2611 or jkoepke@jjc.edu

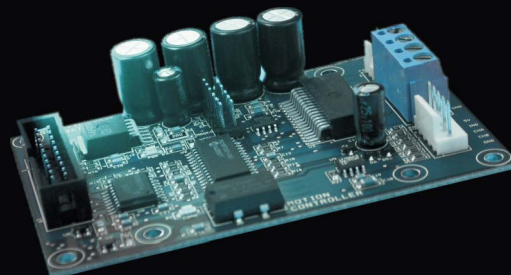
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Sponsorship opportunities are still available for the 3rd Int'l ROBOlympics! Take advantage of the tremendous publicity potential! Robotics is becoming the new lifestyle sport of the thinking age. The Renaissance had music, we have DC motors. ROBOlympics is the channel to a growing audience with both a voice and a high disposable income. Contact us for info on this exciting opportunity: sponsors@robogames.net

Events at ROBOlympics:

Combat: 150g-340lbs and 2 autonomus classes;

Robot Soccer: Humanoid, MiroSot, NanoSot, RoboSot, Aibo, Small League, Middle League;

Sumo: 25g - 3kg;

Open: Robot Triathlon, Ribbon Climber, Line Slalom, Mindstorms Challenge, Best of Show, Maze Solving, Aibo Performer, Balancer Race, Fire Fighting, Mindstorms Open, Table Top Navigation, Vex Open, Vex Challenge, Biped Race, Walker Challenge, Robomagellan

BEAM: Speeder, Photovore, Robosapien Hacker

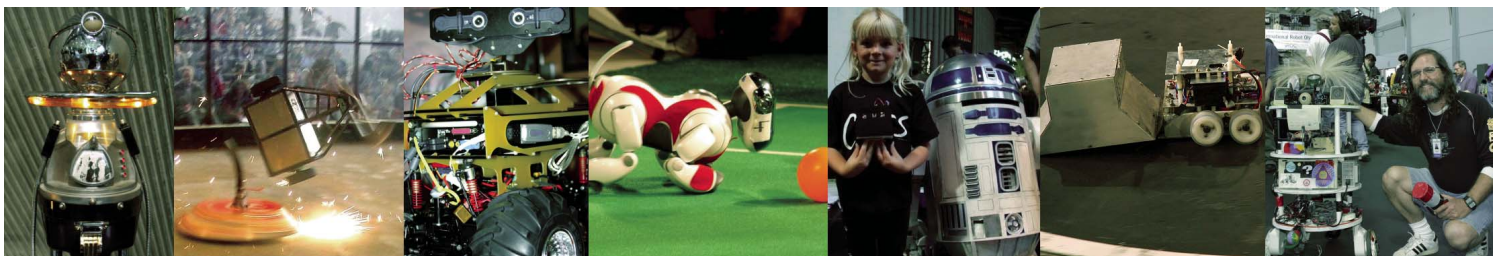
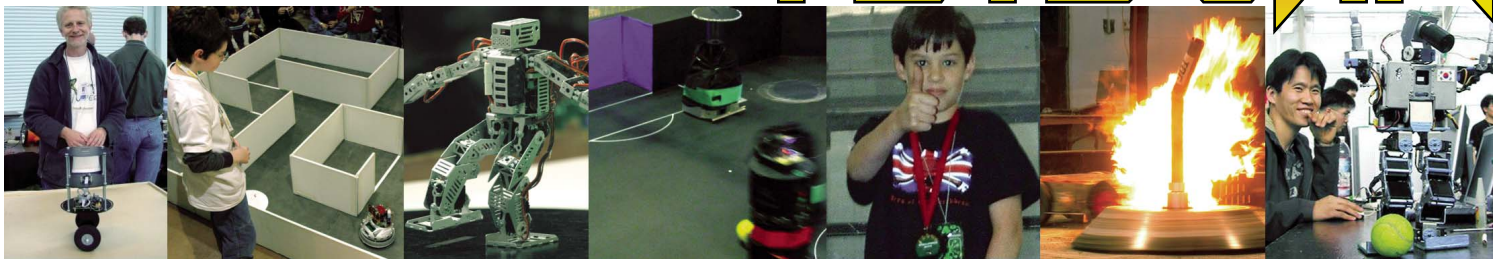
Junior League: Lego - Woots and Snarks, 120 lb Combat (Jr), Mindstorms Challenge, Best of Show, 500 g Sumo, Handy Board Ball, Mindstorms Open, BasketBall Challenge, Vex Open, Vex Challenge

Robo-One: Wrestling, Agility, Stair Climbing, Door Opening, The Eagle, Toss

Art Bots: Musical, Static, Kinetic, Painting, Bartending

Bot Hockey: 3kg & 12 lb
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COMBOTS

SERVO

MAGAZINE

Would You Speak Up, Please

If you'd like to hear a voice other than your own spoken by your next project, Magnevation LLC of Capshaw, AL has just the ticket for you to ride. SpeakJet™ is a single-chip speech

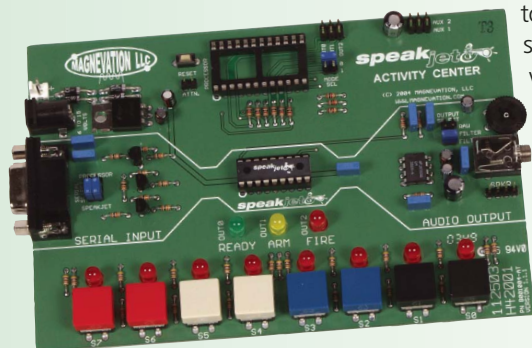
synthesizer and complex sound generator using Mathematical Sound Architecture™ (MSA) that can be tied to an OOPic or BASIC Stamp I/O line.

You can also directly address the SpeakJet via a pushbutton interface. Prerecorded with 72 allophones, 45 sound effects, and 12 DTMF tones (e.g., the tones emitted by a pushbutton telephone), SpeakJet is the ideal solution for implanting a unique set of vocal cords inside your next robot.

In a remarkable nod to robot builders, Magnevation has included two RC input control pins on SpeakJet. These inputs can be triggered via a variable pulse width signal from a conventional RC model receiver for playing up to four pre-canned phrases, sound effects, or control functions.

A supply voltage between 2.0 to 5.5 VDC is all that is needed for powering the SpeakJet.

You can learn more about SpeakJet at www.speakjet.com



The SpeakJet Activity Center is a simple way to create a speech synthesis application for usage in large robot projects.

Is it Just Me, or is This Floor Moving?

If your robot has fallen and it can't get up, then you should study the accelerometers offered by MEMSIC.

These CMOS chips rely on a gaseous proof mass for measuring internal changes in heat transfer which is caused by acceleration. Unlike other accelerometers which use a solid proof mass, these MEMSIC chips are able to handle greater shocks and don't suffer from particle contamination.

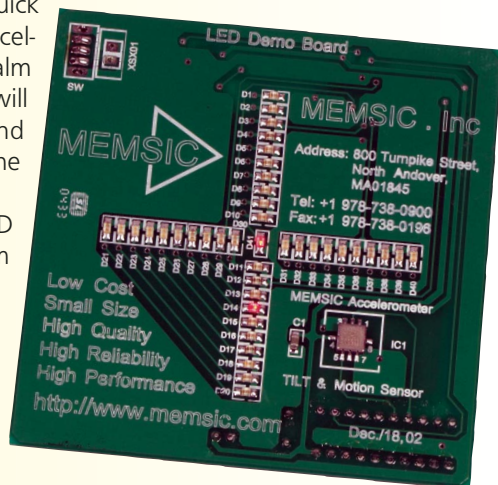
Suffice it to say, that a heat source is suspended inside the chip over an opening which is surrounded by four thermopiles. These thermopiles output a voltage change as the IC moves in the direction of a tilt.

Parallax's Toddler robot uses a BASIC Stamp for reading and reacting to tilt via a MEMSIC accelerometer. If you'd like to play with a simple accelerometer from MEMSIC, then the \$25 LED Tilt Motion Demonstration Board is for you.

This demo board gives you a quick visual reference for tilt, shock, and acceleration. Just put this board in your palm and wiggle your hand. The sensor will read your hand's orientation and motion and display the results on the board's LEDs.

You can order the MEMSIC LED Tilt Motion Demonstration Board from www.memsic.com/memsic/

One tilt in any direction will send this MEMSIC tilt demo board into a blur of LED activity.



The Best Seat in the House?

If you've ever had a dinner party at your house and had to assemble, then disassemble chairs for the event, then the "Robotic Self – Destruction and Self-Healing Chair" might be for you.

You can watch the chair in action at www.youtube.com/watch?v=IEMx0-4Z1jo

Special Summer Bot Session

Are you looking for something kinda robot related to do this summer?

In a recent announcement, LEGO Mindstorms Developer's Program (MDP) has negotiated a special session with SIGGRAPH conference organizers for holding a Mindstorms NXT Developer Program on August 2, 2006.

Traditionally focused on graphic design and publishing, SIGGRAPH has been expanded to include all forms of creativity and providing a forum to the LEGO MDP members seems like a good fit for this new definition.

Described as a conference for "advanced design, engineering breakthroughs, and deep interactivity," these Special Sessions provide attendees with the opportunity to meet the "leading explorers" and see demonstrations of recent technological achievements.

Sharing the same day as the LEGO MDP will be another Special Session, bearing the witty title, "20,000 Bits Under the Sea," dealing with robotic exploration of our oceans. As for the exact title of the LEGO MDP Special Session and the names of these NXT "experts," SIGGRAPH is keeping this information close to its vest.

You can monitor the SIGGRAPH Conference 2006 website for more information at www.siggraph.org/s2006/

SIGGRAPH 2006 takes place in Boston, MA from July 30 to August 3.

RunBot, Run

Okay, at first we all learned how to crawl with our wheeled robots, then we learned how to walk with Robosapien. Now researchers in Europe have designed a biped that can run.

As reported in the March 2006 issue (Vol. 25, Issue 3) of *The International Journal of Robotics Research* (IJRR), the functionally named, RunBot uses a "sensor-driven neuronal controller" for, well, running.

More specifically, researchers Geng, Porr, and Wörgötter claim that RunBot is able to achieve a speed of 3.5 leg lengths per second which they term "fast walking." In order to achieve this gait, RunBot uses a "learning algorithm" for adjusting its sensor-driven controller in real time enabling an acceleration from walking to fast walking within a "few minutes" of learning.

In addition to the abstract for this article, IJRR has also posted two MPEG videos, one big (4.9Mb) and one really big (17.9Mb), that show RunBot in action. You can order the March 2006 issue, read the RunBot article abstract, and watch the robot's video at www.ijrr.org/contents/25_03/abstract/243.html

It's Rainin' Biped

The LEGO® Mindstorms® NXT isn't the only "block toy" robot design kit that is going to be released this summer.

Bioid (the manufacturer says that's Bio + all + oid) by Robotis is a block toy educational robot design kit with a difference — it's one huge kit. Oh, and movable blocks with joint feedback sensors doesn't hurt either. Unlike other promised biped designs, Bioid might be here sooner rather than later.

John Joo, Overseas Sales Department of the Korean Robotis, says that, "We are doing upgrades to our Bioid kit including a new manual and CD disc. It is scheduled to be completed in late May."

You can learn more about Bioid at www.robotis.com

And, if that wasn't enough foot action for you, Kyosho will be releasing the "Athlete Humanoid" MANOI in June 2006. This 1/5th scale biped robot (approx. 15.7" tall) was designed by Tomotaka Takahashi. If you follow high-profile robot designs, then the name Takahashi should be familiar as the designer of the famous 2004 CHROINO; named one of *Time Magazine's* "Coolest Inventions of 2004."

Unlike other bipeds, MANOI is, well, darn right cute. Bearing a strong Anime look, Kyosho says that this robot will have "warmth." While Don Rickles it ain't, MANOI should retail for about \$1,300.

Hey hockey puck, you can learn more about MANOI at: www.kyosho.co.jp/web/race/race_event/event/2005_prsho/w/robot02-e.html **SV**



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APPETIZER

AI and Hobby Robots

by Phil Davis

Artificial intelligence (AI) is a difficult subject to tackle because there are so many different branches. Some are practical and are attainable for the hobbyist and some are way out of reach requiring huge amounts of processing power or extremely technical programs. Not that all hobbyists aspire to delving so deeply into AI, yet may still want to tinker and build cool fun robots without going to extremes. At the end of this Appetizer, I want to leave you with an area you can explore, which I think will provide you with a rich set of tools for your main course — the smarter robot.

So, what parts of AI are freely available to the average robotics hobbyist? Well, first we need to define to some extent what AI means to us. We have all seen “I, Robot” and similar movies in the theater. Clearly, a humanoid robot that can think like us, move like us, make decisions, and effectively get around in our world is a heady goal. While at one end of the AI spectrum — realistically — a free-thinking robot is far out of reach today and possibly for the next 20-30 years. Not to say that we can’t (or at least the Japanese) build robots like Asimo which give a very good impression of being humanoid, but really, it might as well be a radio-controlled car with a bunch of built-in functions. That is, there is no real intelligence there. Even though through its form and elegance of movement it leads us to believe there is, there is no self-determination.

Representing the other end of the spectrum with the charge being led by

iRobot with Roomba, we have this wonderful barrage of robotic vacuum cleaners which have come onto the market in recent years. I certainly don’t think their first model had a lot of utility, but the time was right and they did a terrific job of marketing. Sure enough, thousands of them were purchased.

It seems, that after many years of companies springing to life with personal or home robotic products such as “topo” and “androbot” and then shortly thereafter dying on the vine, that the time has come for the acceptance of home and personal robots. iRobot’s Roomba has been followed by an absolute flock of other robotic vacuum cleaners, my favorite of which is the German one created by “Vorwerk and Infineon,” for use on “smart” carpet which has RFID’s embedded every inch or so. As always the marketplace shows the desires, needs, and wants of the populace. And in a way, validates the need for robots that possess some level of AI.

What makes something like the Roomba so successful? I think that part of its success is that it doesn’t try to be everything to all people. It has one simple functional task which it is quite good at. Of course, it doesn’t hurt that the simple task is a rather repetitive, mundane one which we all hate to do. But this — performance of a simple but useful and functional task — is something I think we will see repeated in a variety of different products over the next few years.

Why? Because it is simple enough that we can actually design

it, program it, and make it work. What an idea! The application of simple AI in everyday products opens the door to other ideas, such as the robotic lawn mower — of which there are a variety on the market — and on the industrial side, the robotic sentry or guard.

Not only has the robots’ time finally come within our households, but high school kids, college kids, and big kids (like me) have become excited and passionate about tinkering with and building robots from LEGO to scratch-built versions. AI adds a new and exciting dimension.

There are many and varied areas where hobbyists are devoting their time, for example, competitions such as Sumo, Mini Sumo and line following which don’t require terribly complex robots. Then, of course, there are more complicated areas requiring more expertise, such as the Magellan competition which requires a large amount of autonomous function. All of this must leave us thinking about what tools there are available to program these robots, thereby providing them with varying levels of autonomy and intelligence.

We can think of a robot suitable for a Mini Sumo competition as having a fairly simple and straightforward task, or set of tasks prioritized like this:

- Don’t fall out of the ring (duh)
- Find the opponent
- Push the opponent out of the ring

Traditionally, we would most likely try to program this by having

a loop in which we checked the rear sensor for the white line, then the front sensor, and then we might check the range finder for the opponent and, if seen, attack and push. But wait, we also need to make sure we are checking the sensors while we push and ... it quickly gets as complicated as that sentence and just as difficult to build on.

So is there a more suitable approach to AI which fits our simple robotic task set and is also extensible? That is, can we build on it to make more complicated behaviors without having to rewrite what we have already done? That would be nice.

Around 1986, Rodney Brooks — who heads up the AI department at MIT — came up with a novel concept or model for programming what we might think of as simple and reactive tasks — the Subsumption Architecture. Subsumption means that behaviors at lower levels are subsumed by those at higher levels, higher being a higher priority or a more pressing need. In the case of the above Mini Sumo task set, the highest priority task is “Don’t fall out of the ring,” triggered by the front or rear sensors detecting the white line. No matter what else might be going on at the time, the behavior to prevent us from falling out of the ring will take over when needed.

Brooksian Subsumption Architecture has been refined and updated over the years and, in my opinion, is ideal for hobbyist’s robots. Why? With this model, it is so much simpler implementing complex behaviors than having a complex and hard-to-maintain loop or case statement. The amount of code required to implement the Mini Sumo problem is relatively small and much more elegant by comparison. I don’t want to delve into this too far, but just to whet your appetite further, Figure 1 shows a diagram describing the Mini Sumo solution in subsumption terms.

The red text represents the sen-

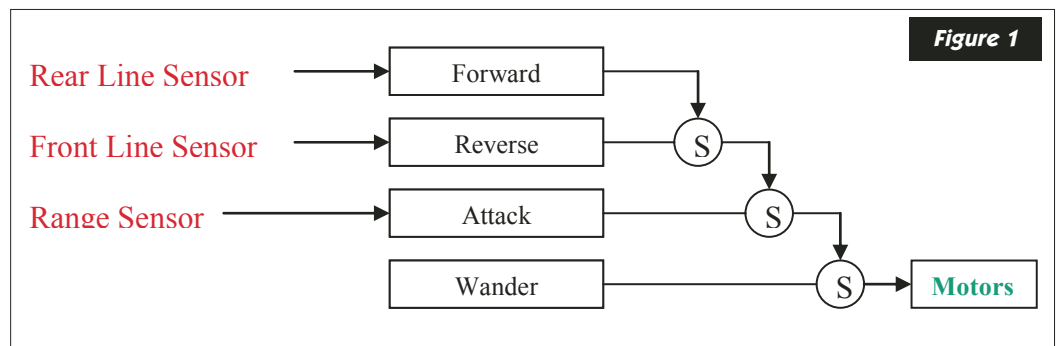


Figure 1

sors which will trigger the behaviors in the center boxes and the circles with the “S” represent suppressor nodes. Conceptually, the robot would start off in the wander mode and if, while wandering, the range sensor is set off by the opponent, the attack behavior which would suppress the wander behavior would be triggered. Then, perhaps while wandering, the front line sensor goes off triggering the reverse behavior which would, in turn, suppress the attack behavior. Once the front line sensor was no longer on and the range sensor was still on, then the attack behavior would resume. Simple and elegant and requiring a minimal amount of code.

This model can be easily extended to include higher level behaviors without dismantling or changing the existing set of behaviors and (before I forget) the behaviors are typically coded in terms of Finite State Automata. (Subsumption uses modified FSA, to allow for behaviors to execute across time.)

The final thing I want to leave you with is the practical implementation of this architecture. Ideally, we want to have all the sensor functions executing at the same time or at least a simulation of them executing at the same time. Also ideally, we don’t want to have to write the code that does that ourselves. Luckily, that is what an operating system is all about — it simulates many processes executing at the same time. This is called multitasking.

Sometime ago, I found an excellent operating system ideal for this purpose: freeRTOS. There are two important words joined together here, the first is ‘free’ — yes, this

operating system will cost you not a penny — and the second word is ‘RTOS’ which stands for Real Time Operating System. This RTOS does both pre-emptive and co-operative multitasking and has messages and semaphores to name a few of its capabilities. In addition, it is ported to a wide variety of processors including the Atmel, which I happen to run it on.

We have introduced several difficult concepts here, subsumption and RTOSs. However, if you make the time to take this approach you will be richly rewarded with a ‘system’ which will allow you to easily construct complex behaviors and which may be extended as required.

For example, if building a robot for a Magellan competition, you might start with a similar model as the Mini Sumo, however, the line sensors would be bumpers and the range sensor would be a sensor looking for walls, trees, etc. Once you had that running to your satisfaction, you could add additional behaviors, such as “search for a red cone” and, at a higher level, “navigate a segment,” thus building on previous layers of behaviors.

I hope this has left you with some food-for-thought and gone some way to show you how to develop functional task orientated robots which you can expand with additional behaviors and perhaps even witness some emergent behaviors which might surprise you. An excellent book on robots and the subsumption architecture is “Mobile Robots” by Joseph L. Jones and Anita M. Flynn. Also, you can Google “robots subsumption” or “subsumption brooks mit.” You can read about and download freeRTOS, from www.freertos.org **SV**



Then and NOW

WALKING ROBOTS

by Tom Carroll

Walking robots have always interested all of us who experiment with robotics whether we want to admit it or not. Let's face it, the ultimate robot is a bipedal machine that is made in the form of a human. All of the first movie robots walked just like people (people were in the "robot suits"). Humans stand upright on two legs, so, the ultimate robot has two legs for mobility. Right?

Of course not, but that hasn't

stopped many robot experimenters from trying to build walking robots. *SERVO* columnist, Pete Miles, is one of those people who have a great interest in walkers — from hexapods to some pretty fancy bipeds that he's demonstrated at our Seattle Robotics Society meetings. I also remember building a rickety walking robot out of Erector Set parts and cabinet hinges while I was in high school. You have to be a bit older to remember using Gilbert Erector Sets with those flimsy stamped metal "beams" and all those nuts and screws.

Considering the set had a constant-speed AC motor with an attached four-speed geartrain on the back, I never could find one of the four speeds that was just right for my legs, so I shortened or lengthened them to fit the gearmotor/legs walking gait and "natural frequency."

It was fairly easy to construct the leg moving mechanism — the hip movement mechanism was the hard part. Thank goodness for the attached AC power cord that I used as a tether as the poor sucker fell over most of the time and I could rescue it with the cord before it hit the floor. The thing looked rather like a drunken baby as it walked like one of those "race walkers" with exaggerated hip motion, but at least I didn't have to cheat and use those "C" shaped feet to keep the center of gravity above each foot as it walked. I did have to use rubber pads on the bottoms to keep him walking somewhat straight. The bottom line is: I had no clue as to how to balance the robot back in those years without using mechanical means.

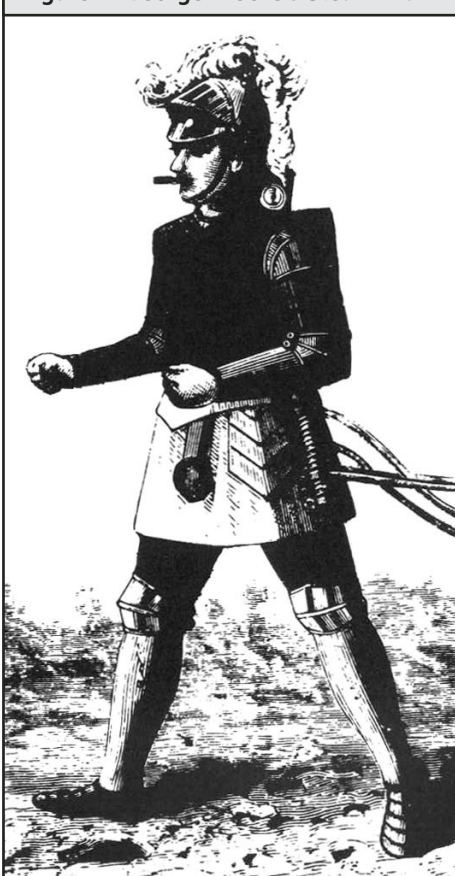
Steam Man

Pete and I are far from the first robot experimenters who have built walking robots. A Canadian engineer/professor, George Moore, built a walking steam man in the Victorian times of 1893 and toured the mechanical curiosity mostly in the US (see Figure 1).

The half horse power steam engine in the man's metal stomach area powered the legs. A gasoline-fired boiler above the small engine had a smokestack protruding out of the six-foot man's head. The engine turned at 3,000 revolutions per minute and it was said that two grown men could not hold the "man" back from walking forward.

This walking machine had no sort of true stability to keep it upright while walking. Stability was provided by a horizontal bar in the "man's" midsection and was connected to a central post to allow the "walking suit of armor" to walk around in circles at nine miles per hour — much like a merry-go-round. I can imagine amazed bystanders on the streets of New York in the late 19th century watching a smoke and steam-belching metal mannequin walking in endless circles as bits of oil and water dribbled down its legs onto the cobblestones. Another variation of Moore's steam man was the fictional Steam Man of the Prairies (Figure 2). In 1865, Edward S. Ellis wrote about a "prodigy that constructed a nonsentient automaton called the Steam Man," so the idea was not new. In the book entitled *Steam Man of the Prairies*, Johnny Brainerd — a teenage

Figure 1. George Moore's Steam Man.



dwarf — invented “a man that shall go by steam.” Could this have been the idea for the first powered agricultural harvester?

Boilerplate

Boilerplate was another mechanical man that was supposedly developed by Professor Archibald Campion during the 1870s as a working steam-powered robot. Note the 1877 date on the carriage in Figure 3. A “prototype” was unveiled to demonstrate the “I Will” spirit of Chicago at the 1893 World’s Columbian Exposition. News accounts mention that Boilerplate was built in a small Chicago laboratory and was designed as a prototype soldier for use in resolving the conflicts of nations. “Boilerplate was eventually able to exercise its propose by participating in several combat actions,” according to various articles. It was said that Boilerplate was taken on a series of expeditions in the mid-1890s to demonstrate its abilities, including a trip to Antarctica.

To celebrate the new century, Boilerplate circumnavigated the globe in 1901 in what turned out to be a failed publicity attempt to accumulate interest in its industrial applications. If this had been successful, the industrial robot would have been developed six decades before Joe Engelberger’s Unimate made the scene. After all, people had always envisioned factory robots as biped androids standing before machine tools designed for humans.

“Even in an age that gave birth to the automobile and airplane, a functioning mechanical man should have been accorded more significance. Boilerplate is a technological milestone that remains largely unknown.” These were the quotes from several respected scientific journals about this amazing invention. The truth of the matter is: Boilerplate — as a truly functional walking mechanical man — was a farce. Campion was a wealthy inventor who made a lot of money on patent royalties from Westinghouse and he tried to build a mechanical man, but failed miserably.

Silver-tongued Archie convinced

brilliant inventors Nikola Tesla and Edward Fullerton (the inventor of the fuel cell), that he was on the right track to fame and fortune. Look at Boilerplate’s tiny feet — a lot of servo corrections would be needed just to keep it upright. It had no horizontal stabilizer bar like Moore’s Steam Man. This technology would not be available for another century. Notice the WWI helmet as Boilerplate emerges from a modern vehicle to a hail of bullets in the Figure 4 cartoon. The bottom line: Boilerplate was strictly a wishful dream in the mind of a slick salesman who managed to drain the bank accounts of people who should have known better. The same goes for the Quasar robot that I wrote about a couple of years ago. There is a cult following of this mythical robot to this day.

Walking Stability

The art of robot stability on two feet is a rather modern feat (no pun intended). Moore’s Steam Man achieved static stability by means of the horizontal bar out one side and attached to the central post. It always stood upright — whether walking or still. Even if a leg fell off, it would still be upright because of the stiff supporting bar protruding out its side. People can find this hard to do, as we have to use dynamic stability just to stand still.

Our feet are not stiff flat plates on the bottom of our legs. As we stand, we can sense the small amounts of pressure on the front and back parts of each foot and can compensate to keep the sensations equal and therefore, standing still. The semicircular canals in our ears act as accelerometers and gyros to sense movement of the head and keep us upright. When sickness, rapid head-spinning, alcohol, or drug interaction causes the liquid in our semicircular



Figure 2. Steam Man of the Prairies.

canals to not act correctly or the sensing hairs to not sense the flow of the liquid, we become dizzy and can fall.

Because cheap accelerometers and gyros were unavailable, and there was the lack of small computers to make sense of the sensor’s signals, walking biped robots did not become available until a century after the steam man. Robot experimenters and designers had to make do with quadruped or hexapod walkers that simulated an animal’s walking.

I-Wei Huang’s Live Steam Creations

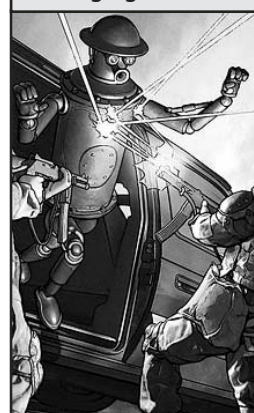
Leaping ahead to the 21st century, I cannot pass up the opportunity to mention some steam-powered robots built in these times. I-Wei Huang has built a half dozen or so Live Steam Creations. These steam walking machines utilize real miniature live steam hobby engines for power.

He also has a steam-powered crab. What appear to be eyes are actually the ends of the two steam engine’s

Figure 3. Boilerplate.



Figure 4. Boilerplate dodging bullets.



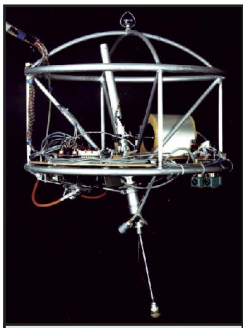


Figure 5. Marc Raibert's one-legged robot.



Figure 6. BigDog.



Figure 7. Lucky.

boilers. These small engines use alcohol, gas, or solid fuel tablets for heat, and they require oiling of the moving parts after about 10 minutes of operation. He says that he has little mechanical skills and uses a Dremel tool and Erector Set parts as proof-of-concept mockups before the final machine is built.

I feel that his mechanical expertise is first rate. Considering that the steam engines have little power, he has to experiment with different gear ratios and setups to make them work. They are really neat, though, when I think of steam and crabs, I'd rather be sitting down ready to eat steamed crabs. I-Wei can be contacted at way@crabfu.com or Google him at CrabFu Steam.

Marc Raibert

I've been concentrating on bipedal robots, but let's go back a few decades to the Leg Laboratory Marc Raibert founded at Carnegie Mellon University in 1980 when Marc was Associate Professor in Computer Science. Rather than just developing robot legs, Marc made himself famous for developing ways of walking and controlling gaits.

The one machine that stands out to most is his one-legged robot (see Figure 5). Yes, one leg. This amazing tethered robot (it had electrical and pneumatic air supply lines) could bounce down the halls of CMU like a basket on an air-powered pogo stick, and could turn corners as directed.

The Leg Lab moved to MIT in 1986 when Marc became Professor of Electrical Engineering and Computer Science and a member of the Artificial Intelligence Lab. Most of the walking robots in use today have used programs and techniques that he developed while at CMU and MIT. He is now president of the company he co-founded — Boston Dynamics, Inc.

BigDog

Marc Raibert "hit the ground running" at Boston Dynamics with his latest and greatest robot — BigDog (see Figure 6). BigDog is being developed by Boston Dynamics with help from Foster Miller, NASA's Jet Propulsion Laboratory, and the Harvard University Concord Field Station. Development of the robot is funded by the DARPA Defense Sciences Office and was designed to carry gear for troops.

Quite a few of us have gone to Boston Dynamic's website and watched the video clip of BigDog in action this March as it walked over small boulders and through mud, and managed to keep upright after being kicked by a person. It reminded me of two skinny sumo wrestlers circling each other, the tops of their bodies hidden in a casket-sized box. The onboard engine powering the hydraulics was a bit noisy, but it can carry a load of 120 pounds at 3.3 miles per hour while climbing a 35-degree slope hill.

Yes, it has four legs, but BigDog represents just how far legged robot science has gone. Lucky, the dinosaur at Disney World (see Ed Driscoll's great January '04 *SERVO* article), is another application of a free-walking bipedal robot that can walk amongst humans (Figure 7). Sure, the nine-foot tall Lucky cheats a bit just like the Steam Man in that he is hooked to a "flower cart" that stabilizes him and supplies the power that he needs. Nonetheless, the Disney Imagineers and their animatronics have again made a world-class robot.

Another biped robot was unveiled this past January. HUBO — the first humanoid robot developed by a Korean research team — was on display for the media during a demonstration at KAIST (Korea Advanced Institute of Science and Technology). HUBO is expected to have capabilities equal to that of Japan's ASIMO — the world's most advanced robot — within the year. Experimenters in basement and garage labs are also creating amazing bipedal walkers using accelerometers, gyros, and microcontrollers that were not imaginable even 40 years ago. Robotics is making some amazing progress these days. **SV**

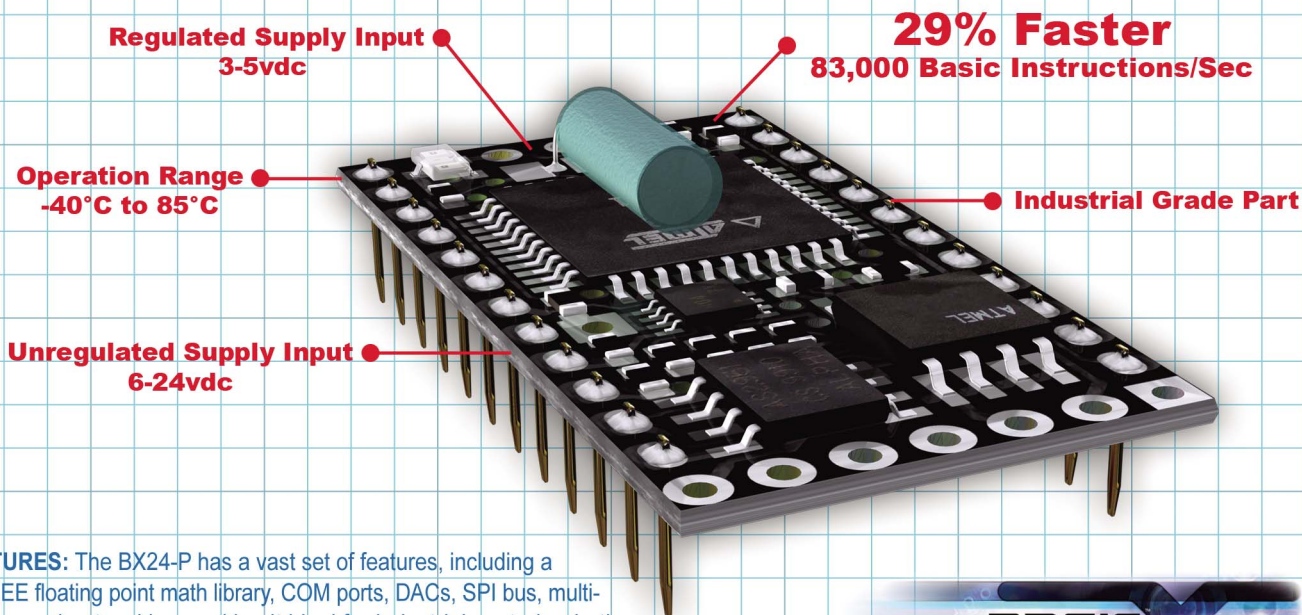
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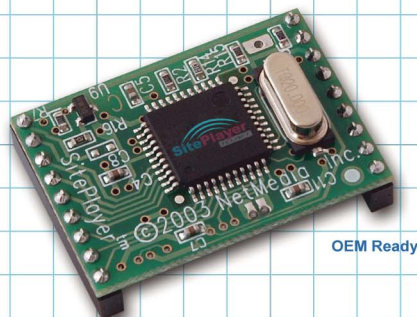
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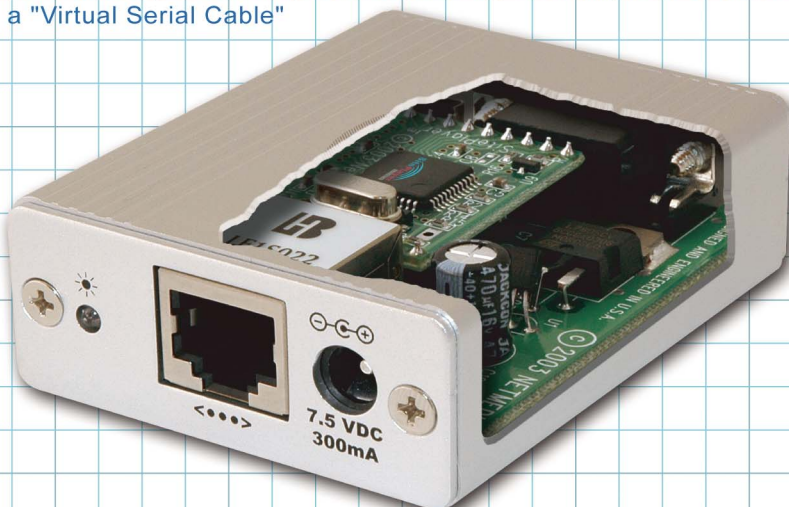


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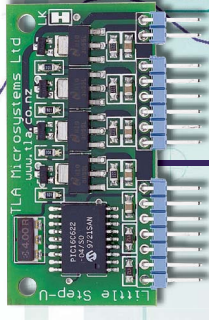
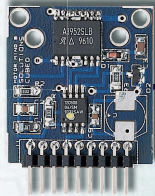
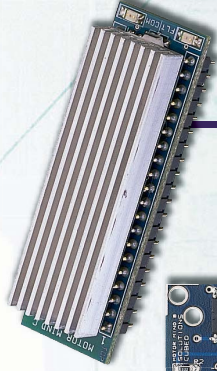
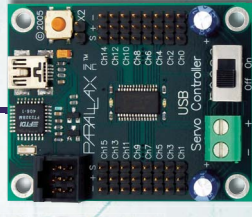
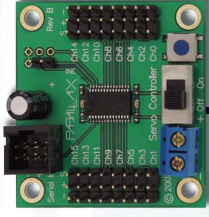
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